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PROCEEDINGS OF THE  
PHILADELPHIA FOUNDRYMEN'S ASSOCIATION.

The regular monthly meeting of this Association was held at the Manufacturers' Club in Philadelphia on Wednesday, January 5, the president, P. D. Wanner, of the Reading Foundry Company, Reading, Pa., in the chair.

Secretary Evans asked those present to state their opinion in regard to the condition of the foundry business.

Mr. Thompson said: "We are not busy, but the past two months have been fair. The volume of business is good, but the prices are low, and the outlook is not encouraging."

Mr. Messick: "We are busier than we have been for a number of years. All our works are in full blast. Last year our business was altogether foreign. This year we are enjoying considerable domestic trade and a little foreign business. We have just introduced our paper machinery into Europe, where it is being enthusiastically received. We placed an order in Finland which revolutionized things there. Our machinery is also going into England, France and Germany, and we now have forces of men there."

W. H. Pfahler: "I am surprised to hear so many gentlemen complain that prices are not satisfactory. That in itself seems

to me a sign of prosperity. The march of prosperity is along the line of lower prices. Nowadays the man with money to lend is forced to accept lower interest; the farmer is compelled to dispose of his product at lower rates, and so it goes. Between the cost of a manufactured article and the price of that article deposited in a bank, there will be shown a large profit, if the manufacturer can afford to lop off all unnecessary expenses."

Mr. Belfield: "I agree with Mr. Pfahler. We have adopted new methods to meet the new conditions, and we are making a profit. Instead of waiting for better prices, which may not come, we are pushing every opportunity that comes to us."

Mr. Devlin: "Affairs in our branch, the malleable iron branch, are not rosy. We have more business, but at lower prices than ever before."

Mr. Green: "In the crucible industry there are better prospects, but very low prices. However, money is coming in promptly and that's something."

President Wanner: "One thought has occurred to me that might bear dwelling upon. I have always regarded Mr. Pfahler as a very bold man, a very daring, but thoughtful man. There is one thing in what he says that challenges consideration. That is the labor question. When we realize that 90 per cent of all that enters into the cost of our products is labor, we must take it seriously into consideration. If we can convince labor that lower prices must prevail, then we are all right for the future. But if that is not believed, then there will be trouble. Such trouble would throw us back further than before. If you believe low prices to be inevitable, then go ahead. We are ahead of any country in the world in our manufactures, but there are certain conditions we must meet manfully."

Mr. George C. Davis, chemist of Thomas Devlin & Co., read the following paper on

#### **ANNEALING OF MALLEABLE CAST IRON.**

The writer had the pleasure in May last of reading before this association a short article on "Malleable Cast Iron," with special

reference to the chemical specifications. The most characteristic part of the process, the annealing, has not until very recently been at all understood. It was generally known that the carbon of the casting was oxidized by the oxygen of the packing, since the carbonic oxide could be seen burning at cracks in the luting during certain stages of the process, and further than that, analysis showed that part of the carbon had been removed. Several writers on metallurgy treat this subject in a very noncommittal way, saying that the oxygen of the air oxidized the carbon—a statement true enough where annealing in sand or like substances was the method described; but these writers carefully refrained from explaining how it was done in the Reaumer process. For if the air were the source of oxygen, we should hardly expect to find the packing reduced nearly to the metallic state, as it is in some cases. One writer in a book published in this city in 1872 advanced the idea that the dissociation of the carbonic acid contained in the gases of combustion was the true explanation, though his assertion was unsupported by any evidence. This view was at least plausible. Then the second difficulty was how the carbon in a solid body could combine with the oxygen of the packing—a very stable substance not dissociated by heat—as it evidently did. The carbon from the casting for 1-8 inch or more had united with the oxygen of the inclosing packing, but how the two got together was an unsolved problem.

It remained for an English metallurgist to show that the process was one of diffusion. Thus if two bars of steel, one high carbon and one low carbon, are heated in contact with each other to a temperature of about 900 degrees C. the carbon diffuses gradually from the one to the other. This experiment was conducted in a porcelain tube in vacuo. And it is a similar diffusion that brings the carbon of the casting into contact with the oxygen of the packing.

At the meeting of the British Iron and Steel Institute held in May of last year there was presented by G. P. Royston a paper on "Malleable Cast Iron," which with the discussion that followed has doubtless been read with great interest by makers of malleable

castings in this country. This paper, so far as it presents what we may call the practical details of the process, brings out certain marked differences between British and American practice, so comment from the latter point of view may be of interest. Both Royston and Hadfield take the ground that manganese in appreciable amounts is injurious. The pig iron used in the experiments contained 0.112 per cent and the casting 0.043 per cent manganese, thus showing more than the usual loss in melting. I have never found any good casting that was made in this country that ran as low as this, even those made from charcoal iron exclusively. The average analyses of three typical brands of charcoal iron for the past year show for the No. 2 grade 0.24, 0.32 and 0.45 per cent respectively, and for the No. 4 grade of the same brands 0.19, 0.14 and 0.18 per cent. The leading brands of coke malleable run still higher in this element; one contains from 0.60 to 1.00, another 0.60 and a third well-known brand from 0.20 to 0.50. A few concerns use small quantities of pig containing 3 per cent manganese, but this is with a view of producing a smooth and solid casting free from pin holes. We see from these figures that it is impracticable with the pig at our disposal to produce castings as low in manganese as is held to be absolutely essential by the British writers, even were this result desirable. And I do not think that it is. In this country the most common practice is to make a mixture containing from 0.40 to 0.80 per cent manganese, which would give from 0.20 to 0.40 per cent in the castings.

Whatever reason there may be for claiming that castings containing manganese anneal with difficulty, since carbide of manganese and iron is more difficult to decompose than carbide of iron, the fact remains that according to the writer's experience in actual practice castings of the composition mentioned above, are annealed without the slightest trouble, the combined carbon being below 0.10 and frequently only a trace; the graphite of course depending on the cross section of the casting and time of annealing. A number of tests and analyses by a Western concern show silicon, 0.75 to 0.98 per cent; manganese, 0.35 to 0.53



per cent; tensile strength, 39,600 to 53,700 pounds; elongation, 3.85 to 7.83 per cent. Unfortunately, the carbons are not given, but it is obvious that to obtain these results the annealing must have been good. Sulphur, if present in large amounts, interferes with annealing, as was shown in a paper by H. R. Standford, read before the American Society of Civil Engineers in 1895.

In melting iron in an air furnace using a coal containing 1.12 per cent sulphur I found the metal gained not over 0.03, so that the casting never ran over 0.06 per cent. Some castings are made from iron melted in a cupola, and here it occasionally happens from bad fuel or irregular melting of the sprues in the charge that the sulphur runs too high. In a previous paper I referred to an extremely tough casting containing 0.121 per cent sulphur. This casting was about 1-8 inch thick, and had the carbon practically all removed. In the case of a thicker casting where the annealing did not remove all the carbon I found a slightly larger amount of sulphur sufficient to prevent complete annealing. A casting 3-8 inch thick after once annealing showed sulphur, 0.133 per cent; graphite, 0.547 per cent; combined carbon, 0.515 per cent.; after a second annealing, graphite, 0.505 per cent; combined carbon, 0.380. Using the best fuel obtainable and the greatest care in charging it is possible to melt iron in a cupola without adding more than 0.03 per cent sulphur, but I find that few works can show as good results as this, and more often 0.06 or over is added than the former figure. West Virginia coke running from 0.50 to 0.65 per cent sulphur and Connellsville at about 0.85 per cent can be easily obtained, so it is entirely practicable to produce castings from cupola metal running below 0.11 per cent sulphur, an amount not objectionable in the class of castings made from this iron.

The difference between Reaumur's process, where the carbon is wholly or partially removed, and the process described by Forquignon, where it is simply changed to graphite or decarburized and transcarburized respectively (as one author puts it), is fully brought out in the discussion of Mr. Royston's paper. Many manufacturers of malleable iron in this country do not

understand this matter. Some of them use various processes for annealing which do not decarburize to any appreciable extent, under the impression that they are producing Reaumur castings. A number of processes for the production of malleable castings have been proposed by men ignorant of the rationale of the Reaumur process. It is impossible for commercial reasons to discuss them here; suffice it to say they are no improvement and many are obvious frauds, such as the addition of mysterious fluxes in the furnace or ladle just before pouring. In the discussion Mr. Hadfield takes issue with Mr. Royston, who says no bend can be obtained if the graphite is present as in the so-called black heart castings such as are produced by annealing in sand or bone ash in luted pots. Mr. Hadfield instances a casting made in this country containing 3.07 per cent graphite, which could be bent in a manner approaching soft steel and had wonderfully good resisting properties to sudden blows. My own experience agrees in the main with Mr. Royston. While castings containing large amounts of graphite will sometimes bend well, I have never found them as tough as decarburized castings containing equal amounts of the other weakening elements, silicon and phosphorus.

In this country roll scale is used as a packing in preference to ore for several reasons. Ore sufficiently low in silica would be more expensive for works located east of the Alleghenies. Mill scale requires no grinding or other preparation than to oxidize or rust it, as the common saying is, with a weak solution of sal ammoniac. Instead of mixing three or four parts of spent ore with one of raw ore ground to the size of a pea, as described by Mr. Royston, it is common practice to spread the spent packing on the floor and sprinkle it with a weak solution of sal ammoniac so that the mass becomes oxidized. This spent packing is, of course, finely divided as it falls through the crevices in the tumblers into which the whole charge is placed. The oxidized mill scale is added from time to time, as there is always some loss in handling the packing as dust and in other ways. So far as the pots are concerned no special mixture is made for them.

They are cast from cupola metal, if this is available, and last five or six heats, depending on their position in the furnace. A number of types of annealing furnaces are used. Probably in the most efficient type the fire is built in furnaces along one side, the gases entering near the top, passing across the furnace down the opposite side and out of the ports to by-pass flues underneath the floor and finally to the stack. Thus all sides of the furnace are heated to a nearly uniform temperature.

Mr. Royston refers to the question of scaly castings without covering the whole ground. In speaking of annealing in sand or bone ash, he says: "The reaction taking place between the carbon and the iron should be  $C+O=CO$ . Should it be  $C+O^2=CO^2$ , the iron will also be oxidized by the carbonic acid and the casting will be scaled." To put it in other words: If you use too much air you will burn the castings. Continuing, the author says: "Where oxides of iron are used as a source of oxygen the carbon monoxide partially reduces the iron-oxide to the metallic state." This sentence is of doubtful meaning, but I take it that he intended to say reduces the iron of the scale to the metallic state. It frequently happens that where a number of small castings are annealed in ferric oxide in the same pot some will scale and some will not. I have never found a scaly casting that contained the amount of manganese usual in good castings, and I believe that this element acts to prevent scaling, at least when annealing in ferric oxide. Thus in one case, a scaly casting showed 0.08 per cent, and a good casting 0.27 per cent manganese, both being annealed at the same time. With regard to phosphorus, if the Lorn pig used in Mr. Royston's experiment is one of their representative brands the English founders seem to be running lower in this element than is necessary. I certainly do not believe in adding phosphorus ad libitum, but in this country the usual specification is 0.20 or less, and certain it is that castings containing 0.18 (that is about a fair average figure) show excellent results.

No discussion followed this paper.

George H. Robbins, of the Clement Pneumatic Tool Company, Philadelphia, read a paper on

#### **IMPROVED PNEUMATIC TOOLS FOR FOUNDRY USE.**

The use of pneumatic tools for cleaning and chipping castings is not new. Certain defects in the old style of construction, the want of knowledge of how to operate them, together with the prejudices of ignorant workmen, have resulted in eight cases out of ten in the condemnation of the tools for foundry use. The first thing we will deal with will be the objectionable features of the old style of tools, of which the recoil or kick was the most noticeable. This recoil or kick has done more to prevent the adoption of large sized pneumatic tools than anything else, as it has enabled the workman who is afraid of losing his place to say, with some appearance of truth, that holding the tool was injurious to him, producing paralysis of his arm, etc. To this, and here, let me reply that I know of men who have been running pneumatic tools continuously for the past five years, and who have not been affected in the slightest by them in any way whatever. The improved Clement valveless tool is so constructed and so evenly balanced that all kick has been eliminated from it, because it has an air cushion so placed that when in operation the workman is really pushing against air, the elasticity of which takes up all shock and vibration.

Another important objection that is made to the old style pneumatic tool is that so many small parts, valves, springs, etc., enter into its construction. Such a number and variety of parts make the tool very delicate and liable to get out of order.

The improved Clement valveless tool consists of but three parts or pieces—a cylinder that is bored out of a solid piece of steel, a hammer or piston made of tool steel, and a butt piece or plug to close the end of the cylinder. The only part of it that moves is the hammer, and that is not dependent upon the movement of any other part for its own motion. If it is given fair treatment and regularly oiled it can be depended on for a long period of steady and reliable service, and knowing this we are warranted in guar-

anteeing it against all repairs for two years. This, I trust, shows plainly and conclusively to any investigator that the objectionable features in the pneumatic tool of the past are not to be found in the improved Clement tool of to-day.

Let me now speak a moment of the ignorance of operating, and the prejudice existing against pneumatic tools and the reason therefor. No doubt some of you have had pneumatic tools tested in your foundries and perhaps unsuccessfully. Have you, however, considered in such a case how this test was made? Pneumatic tools are made in many sizes, and to use them to advantage they must be used for the purpose to which they are adapted—that is, a small tool for light work and a large tool for heavy work. Then again, at what air pressure did you try this tool? Do you know whether the pressure used was high enough to develop the efficiency of the tool? And, last, but not least, in whose hands was the tool placed for trial? Was he a man who would work for your interests, forgetting his own, or was he opposed to the tool because it was a labor-saving device and because its adoption was liable to bring about the discharge from employment of himself or some of his shopmates? These are all-important considerations, and may explain to you why the test of pneumatic tools in your shop was a failure, if such it was.

The best way to introduce the tools is to place them in the hands of young men, who are, as a rule, ambitious, and who will take a pride in running a new machine. Let them know that the successful operation of the tool will mean a slight advance in their wages. If on the contrary, however, you give the tools to a man who believes only in old hand methods, the amount of work that he will turn out will be small, comparatively speaking. The average amount of work that can be done with these tools is as follows: In removing sand from large and heavy castings, one man with a medium-sized tool, and a broad chisel, can readily do as much work in a given time as six men could by hand methods.

One man with a tool can do as much light fin-clipping as is usually done by five men in the same period of time; and when it

comes to rough or heavy clipping, one man with the proper sized tool can do about the same quantity of work that is generally done by three or four men with the hammer or chisel.

It is sometimes necessary to do chipping to a line, or true surface. A man who is skilled enough to do this class of work with a hammer and chisel can accomplish just twice as much in the same time by using a pneumatic tool for the purpose. The operator has absolute control over the tools used for this fine work; striking a light or heavy blow, as he desires; governing the force of the blows by the simple pressure of his hand, and not by throttle valves, etc., that are so liable to wear out.

If anyone should doubt the possibility of the operator being able to cut to a line, or having this perfect control over the tool, it affords me pleasure to refer you to the marble and granite cutter, who not only does the most delicate carving and lettering with the tools, but does it on a substance that is vastly more friable and brittle than cast iron.

Before concluding, I ought perhaps to say a few words about air plants when used in connection with pneumatic tools. In the first place, an air compressor, an air receiver, and a lot of different sizes of pipe strung around a shop, do not always constitute either an efficient or economical air plant. To get the best results, you require:

First—An air compressor of approved pattern, of sufficient size and power to develop and maintain a steady pressure of 80 to 100 pounds to the square inch.

Second—An air receiver of sufficient size to equalize the pulsations of the compressor, and to cause the air to flow with uniform velocity to the tools.

Third—As air in its passage through pipes is subject to friction, in the same manner as water, it is important that your pipe system be carefully designed, as loss by friction may be quite serious. In calculating such loss, it would be well to remember that the difference in pressure between the entrance to the pipe and the point of use, termed in hydraulics "loss of head and power

lost," is not applicable to compressed air. Compressed air will lose 10 per cent of its head, but the loss of power will only be about 3 per cent. The reason for this is simple, when you remember that compressed air as it loses in pressure gains in bulk, and thus in a measure by its increased volume compensates for the diminished pressure.

#### DISCUSSION.

Howard Evans: You do not mention the amount of power required to drive the compressor, nor state the saving over hand work where tools are used. You only say that one man can with one tool do so much more work than by hand.

Mr. Robbins: An air compressor of a size sufficient to operate say three tools, 14-ounce hammers, would require four-horse power to run it—that is, a belt compressor. When a small compressor can be used it is much more economical to run it by belt power than by steam direct. The cost of such a compressor would be in the neighborhood of \$180. The cost of the air receiver would be about \$40, while the cost of the pipe would depend altogether on the distance the air was to be carried; if 100 feet say \$5. Three tools of the capacity mentioned would cost say \$300. A total cost of about \$525 for the equipment.

Mr. Evans: Where people have a compressor in use the adoption of these tools is accompanied with considerable less expense, is it not?

Mr. Robbins: Certainly. I have here a small 2-ounce tool, the earning capacity of which is \$900 per annum. That is the earning without the expense. The tools actually save the labor of one man for 300 working days in the year. The outfit I have mentioned is large enough to run six of these tools. In taking sand off castings you would require a broad chisel like this (showing a chisel with about 2-inch cutting edge).

Mr. Messick: Are the tools in use in this city?

Mr. Robbins: Yes. They are in use at Cramp's, and at the works of the Warden Manufacturing Company, in both boiler shop and foundry. They are used in shipyards for chipping and



calking. When used for calking a man can calk 60 lineal feet per hour. On boiler work about 40 feet. It makes a tighter joint than is possible by hand, the blows not being so hard, but multitudinous. The tool I have shown you uses 10 feet of air per minute at 80 pounds pressure. It can be operated with a pressure as low as 60 pounds, but high pressure is the best, the resulting work being much more efficient.

Mr. Messick: Did you ever try driving rivets with them?

Mr. Robbins: Yes, what you call shell rivets, 3-8-inch cold rivets. A 6-pound hammer will drive them faster than you can put them in the hole.

Mr. Eldridge: Supposing one wished to knock off a riser from a casting, say a riser 2 inches in diameter, would you smooth the casting with the tool as well?

Mr. Robbins: A sledge would be better for knocking off a gate of that size. After the gate is knocked off you can smooth down with the pneumatic tool.

Mr. Evans: Supposing a foundryman having a compressor wished to try these tools, would you give him a trial?

Mr. Robbins: Certainly. He could have them for ten days on trial, and we would visit his foundry and impart all instruction possible.

## **PROCEEDINGS OF THE WESTERN FOUNDRYMEN'S ASSOCIATION.**

The regular monthly meeting of the Western Foundrymen's Association was held Wednesday evening, January 19, 1898, at the Great Northern Hotel, Chicago. In the absence of the president, William Ferguson, Vice-President, occupied the chair.

Mr. Malcolm McDowell read the following paper:

### **VALUE OF METALLOIDS IN CAST IRON.**

July 12, 1896, I read before the Western Foundrymen's Association a paper on the practical value of the various metalloids in cast iron, in which I outlined a series of experiments to demonstrate the influence that silicon, phosphorus, sulphur, and manganese exert when combined with iron in various proportions, and then a combination of the different metalloids in various proportions with iron to ascertain not only the individual value of each, but what combination of metalloids with iron will give the best metal for all the various uses a foundryman is called upon to make. Whether metal is graded and sold by fracture or by chemical analysis, its value is determined by its constituent elements, so that the experiments proposed are of equal value to the furnace as to the foundryman.

The Western Foundrymen's Association appointed a committee of three to carry out my suggestions, but on account of the depressed condition of business during the year, nothing definite has been done by them. I desire, therefore, to present for your consideration further ideas on the same subject, showing the value of even a limited knowledge of the various metalloids that combine with iron in making high grade castings, and by varying their proportions show their influence in different physical tests.

Pursuing a similar course to ascertain what brand or brands of pig iron will give the best result in making castings as that I propose in ascertaining the value of the various metalloids that

combine with iron, and after establishing a known basis in practical work I analyze both the pig metal and the castings it makes, and then identify this analysis of pig iron by fracture of the same, to establish a gradation of metal by fracture. This can be done, and holds good, so long as that special lot of iron lasts, but is liable to be vastly different when a new lot of metal is bought; for independent of the constitutional elements that affect the fracture, the temperature at which a cast of pig iron is made, and the length of time it has to cool, will influence the nature of the fracture. The fracture of a sow, hot and cold end of a pig, will show a difference in the structure of the fracture that would cause a grader in grading by fracture to give the same metal three different numbers, when each practically analyzes the same. It is not an unusual thing for a furnace which grades by fracture to sell to a foundryman a No. 4 foundry pig, when upon analysis, the foundryman finds it equal to No. 2 foundry. It would be more profitable for a furnace to sell, and quite as satisfactory for a foundry to buy, by chemical analysis.

A combination of metalloids with iron that will make a good dry sand roll, pinion or gear wheel, would not do for stove plate, wagon skein, or cast iron water pipe. It is one thing to make a high grade, strong casting, having a tensile strength of from 35,000 lbs. to 40,000 lbs. per square inch, and quite another to make a water pipe out of the same metal. It is possible to make a cast iron water pipe that will carry over 30,000 lbs. tensile strength per square inch, but the combination of metalloids would be different in each kind of casting.

To illustrate the following tables of three heats: The first two were preliminary heats made to test the practical value of different brands of pig iron, and were made according to what the fracture would indicate from their constituent elements, and the third heat was made after the experience had in testing the physical properties of the other two heats, and then having the pig iron out of which they were made, as well as the casting they produced, analyzed. This information enabled me to make the third heat intelligently from selections of pigs whose chemical constituents were known.

	Silicon.	Phosphorus.	Sulphur.	Manganese.	Deflection in 1" sq. bar, 24" between centers.	Trans. str. in 1" sq. bar, 24" between centers.	Tensile str. of 1" sq. bar.	
Heat No. 1.....	1.92	.80	.081	.43	.40	1,425	26,000	Good Pipe.
Heat No. 2.....	1.40	.57	.082	.54	.35	1,465	29,000	Heads Off.
Heat No. 3.....	1.68	.50	.025	.75	.44	1,500	32,000	Good Pipe.

The first heat was too rich in all the metalloids to make a very strong casting, but it made good pipe; while the second was too high in sulphur, and too low in silicon to make a cast iron pipe, for although the casting was strong it did not come up to the requirements. Out of the experience had in the previous heats, both in physical and chemical analysis, the third heat was evolved, which metal met all the requirements, in quality of pipe, and strength of metal.

Blast furnaces have regular grades of iron, running from No. 1 to No. 6, varying this in some cases by adding an "X" or a "P" as No. 2X or No. 2 Plain, and substituting names instead of numbers, as gray, mottled and white forge, and calling some grades No. 1, 2 or 3 soft. Most furnaces, all but a very few, in fact, grade their product entirely by fracture, and as a consequence what is No. 1 in fracture from one furnace is not like No. 1 from another furnace. A few furnaces grade by chemical analysis, but they are very few, and even these, to satisfy the requirements of many of their customers, have to make part of their grading by fracture. And still the commercial value of pig iron depends entirely on its chemical analysis.

While I do not claim the following table is accurate and up to date, it is sufficiently so for me to make plain what I wish to illustrate.

	Price per ton.	Total Carbon.	Silicon.	Phos- phorus.	Sul- phur.	Manga- nese.
No. 1. Foundry.....	\$12.00	3.68	2.90	.75	.01	.30
No. 2. Foundry.....	11.50	3.30	2.25	.70	.02	.40
No. 3. Foundry.....	11.00	3.25	1.50	.30	.03	.50
No. 4. Gray Forge.....	10.50	3.80	1.00	.65	.04	.62
No. 5. Mottled Forge.....	10.00	3.75	.70	.50	.05	.05
No. 6. White Forge.....	9.50	3.65	.40	.35	.10	.96

A practical foundryman looking over this table will readily pick out the two columns that give value to pig iron in his work, those of silicon and sulphur. The money column shows a difference between \$9.50 and \$12 of \$2.50, while the silicon column shows a difference of 2.50 per cent in silicon, making each one-tenth of one per cent silicon worth ten cents.

It is estimated that each atom of sulphur neutralizes ten of silicon. When pig iron carries three or more per cent silicon, it is called a "softener;" when it goes between three and five per cent, it has various names, such as "silvery;" and after it goes above five per cent, and from that to ten, it is called "ferro-silicon." This carries less sulphur in proportion to its silicon than any other form of pig metal, and as a softener is a question of silicon, 10 per cent "ferro-silicon" is the cheapest softener that can be bought.

While pig iron, softener and ferro-silicon prices are all measured by the amount of silicon the metal carries, high silicon iron alone will not make a good casting. It requires a proportionate amount of manganese to insure castings that are strong, solid and free from sponginess. A foundryman should keep on hand at least one carload of 10 per cent ferro-silicon and one ton of 80 per cent ferro-manganese. Equipped with these two and a coke that will run less than .75 per cent sulphur, he can meet any requirements in castings, even if he has nothing but common cast scrap iron to work with, or an off pig, provided he has an intelligent knowledge of the use of these two metalloids.

When all other things are equal in pig iron, the variation in silicon will be manifest in the fracture, provided it is made and cast at the same temperature. Each of the three metalloids, phosphorus, sulphur and manganese, varying in their proportions, also affect the nature of the fracture, as do also the different degrees of temperature at which the metal may be cast, and the condition of the atmosphere at the time of casting. These are the causes that make it impossible to make a uniform gradation of pig iron by fracture.

All blast furnaces making metal for steel works meet the requirements of the steel maker by furnishing a metal having a specific analysis, while a few exceptional blast furnaces making a foundry metal, grade their output by fracture. They do not care to employ a chemist to grade it systematically according to its constituent elements by analysis. There are a great many foundries that employ to a greater or less extent a chemist to analyze the pig iron they buy and castings they make, and in buying metal graded by the furnacemen according to fracture, they have been enabled by the use of chemistry, to duplicate their orders very much to their profit and the furnacemen's loss. In justice to both furnace and foundryman, pig iron should be bought and sold by analysis. One of the most important things to be accomplished by the united efforts of the various foundrymen's associations is to establish a gradation of pig iron based upon chemical analyses so that the metal can be bought and sold on its merits as exhibited by its constituent elements.

In melting iron in the cupola a loss of from 4 to 10 per cent is sustained. Almost all of the loss of metal is in the metallic iron, but a portion comes from the various metalloids contained in the original pig metal.

The per cent of iron in the original pig metal is 93.37, leaving 6.63 per cent of metalloids to work with in making castings. The iron in the finished casting is 93.60 per cent, leaving 6.40 per cent of the metalloids, making .23 per cent that is eliminated. It is hard to realize that such a small percentage is what we have to do with in making various grades of castings.

In the Methodist Church, of which I am a member, much is made of personal experience, and when a good brother gets tangled up on some questions of theology, his way out is to fall back on his personal experience. Now, if I were to undertake to make a scientific explanation of all the whys and wherefores, I would soon find myself in the condition of my pious brother, and, therefore, ask your indulgence in giving you my personal experience in the use of a limited knowledge of the value of the metalloids that combine with iron in making castings from a

cupola melted metal. One who undertakes to make new improvements makes many failures; and if out of the many efforts one success comes, he is justly proud of it. If I manifest some pride in the following report, you, who like me, have had your share of failure, will congratulate me on this one success.

The following is the report of Maj. J. W. Rieley, commandant, Watertown Arsenal, on some cupola metal made by me to demonstrate to the United States Ordnance Department that it was possible to make in a cupola a metal costing less, but superior to gun metal, which they specified "should be charcoal pig melted in a hot air furnace," the tensile strength to be not less than 27,000 and not to exceed 38,000 pounds per square inch:

ORDNANCE DEPARTMENT, U. S. A.

Report of Mechanical Tests Made with the U. S. Testing Machine, Capacity 800,000 Pounds, at Watertown Arsenal, Mass., December 28th, 1894.

Tests by Tension. Cupola steel for Malcolm McDowell, Chicago, Ill.

Nos. 5,170 and 5,171 had stems 2 inches long, turned down from 1 inch square cast bars.

Nos. 5,172 and 5,173 were turned down to grooved form of specimens from 1½ inch round cast bars.

Test No.	Diameter, inches.	Sectional.		Pounds sq. inch.	Appearance of fracture.
		Area sq. inches.	Total pounds.		
5170	.564	.25	12,300	49,200	Fine Granular.
5171	.564	.25	11,460	45,840	Fine Granular.
5172	1.129	1.00	46,400	40,400	Fine Granular.
5173	1.129	1.00	42,820	42,820	Fine Granular.

J. W. RIELEY,

Major Ordnance Dept., U. S. A., Commanding.

This metal was condemned at first by the ordnance department, because it went over 38,000 lbs. per square inch tensile strength. It was claimed that when it did so, the metal was too "cold-short." This idea arose from Capt. Rodman's report, made away back in the fifties. Capt. Rodman, after selecting various brands of the best charcoal pig he could find, took three of them



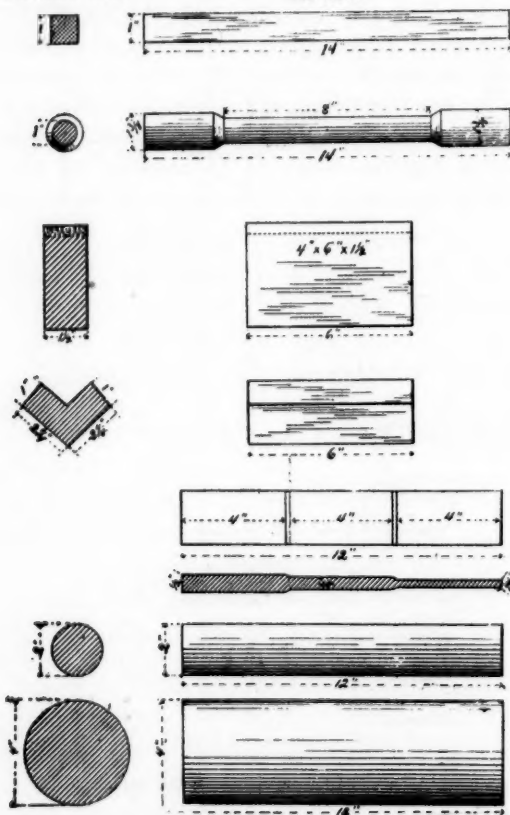
TABLE B.

Number of heat.	METALLOIDS.						PHYSICAL.				Fracture.	SOLIDITY AND HOMOGENEITY.	FLUIDITY.
	Combined carbon.	Uncombined carbon.	Total carbon.	Silicon.	Phosphorus.	Manganese.	Sulphur.	Transverse 12 in. 1 in. square.	Tensile 1 in. area.	Deflection 12 in. center.	Contraction 8 ft. bar.	Depth of chill. 1½ in. x 4 in. x 6 in. block.	
1	.83	2.19	3.12	1.34	.08	1.00	.023	4300	40000	.14	.....	½ in. chill. 2½ in. gray. finer, homogeneous casting.	.....
2	.70	2.60	3.30	2.00	.64	.80	.025	2400	28000	.10	¾ in. 1-16 in.	Open in the center. uneven fracture, dark gray.	Edges and corners full and sharp, smooth surface.
3	.75	2.54	3.29	1.92	.60	.79	.027	2700	30000	.10	¾ in. ¼ in.	Uniform fracture and dark gray.	Edges not sharp, but corners full; smooth surface.
4	.80	2.44	3.24	1.79	.57	.78	.029	3100	34000	.10½	1 in. ¼ in.	Uniform fracture, but a bright gray.	Edges and corners rounded off; surface tolerably smooth.
5	.86	2.39	3.25	1.67	.55	.77	.032	3400	35000	.10	1½ in. ¾ in.	Fine, uniform fracture, but a bright gray.	Edges rounded off; corners of ¼ wasted— not full. Surface rough.
6	1.00	2.35	3.25	1.58	.50	.76	.034	3500	36000	.09½	1½ in. ½ in.	Very fine and uniform fracture; bright gray.	½ of the ¼, and ¼ of ¼ wasted. Castings not run full.

which he considered best, and then after refining, which was done by remelting two or three times, he cast his metal into cannons. The preliminary heats made in his first test showed over 38,000 lbs. tensile strength and the metal was hard and brittle. This

Sectional View.

Side View.



Physical.

Fracture

Solidity and Homogeneity.

Fluidity.

Machinability.

TEST BARS USED FOR OBTAINING TABLE B.

was condemned on account of its cold-shortness; but test bars from subsequent heats, which were not subjected to so much heat, showed less than 36,000 lbs., and having more elasticity

the metal was accepted. It was claimed the cause of the failure of the first heat was that it was too much de-carbonized in the furnace, while the second heat was drawn earlier, and, therefore, it is claimed had more carbon. It was not for a lack of carbon but for a want of silicon.

Table B represents six different heats. No. 1 of this table is the same as No. 5,170 of the Ordnance Department's report, and it is placed here in this table to show what is possible in making a metal high in transverse and tensile strength, with a large amount of elasticity, due to the lowness of phosphorus and sulphur, and which is easily machined. You will note that the percentage of nearly all of the metalloids is lower in this heat than in the others, while the heat is highest in transverse and tensile strength. This is due to the special proportions of silicon and manganese, as they are at the points where they exert their best influence on the carbon in combination with the iron, and the carbon being free from the influence of the phosphorus and sulphur in its combination with the iron, leaves the metal with more than usual amount of elasticity. It is these conditions that make the metal tough, not hard, in turning and machining.

Now follow the lines and columns of the other five heats. The carbon is very near the same in all, while there is a gradual decline in the other metalloids, excepting that of sulphur, which, in like proportion, increases; and the transverse and tensile strength, as the metalloids are reduced, increase, but the elasticity is reduced. The bar of No. 2 broke before it reached 3,000 lbs., and bar No. 3 broke at only a little higher, each registering .10 inch deflection. The only reliable figure in this column is at No. 4, which at over 3,000 lbs. registered .104 inch deflection. In the subsequent heat, No. 5, it fell to .10 and in No. 6 to .093 inch, the carbon remaining the same, but the silicon going down, showing it is a want of silicon and not carbon that reduces the elasticity of iron.

The next three columns are full of interest, as they show the depth of chill, the amount of shrinkage in a bar 8 feet long, and the nature of the fracture. The last three columns have to do

with questions of great importance:—What combination of metalloids will make a casting free from sponginess in the corner of a flanged casting? What will make a metal of sufficient fluidity for making special castings? How low can you run silicon in combination with the other metalloids to secure the greatest strength and solidity, and be easily machined?

Table B is a tabulated statement of my personal experience in making castings with the limited knowledge I have of the value of metalloids that combine with iron in castings made from metal melted in a cupola.

Before reading this paper Maj. McDowell made the following remarks: In order to render me what assistance is necessary, I wish you to take a copy of the paper and follow me until we come to the tables, which I shall merely refer to as a table. The paper simply as a paper to be read off has but little significance, except as reference to these tables, for the tables show the entire drift of the value of the metalloids. So if you want to get the correct idea you will want to study the tables as we come to them. It is one of the most intensely interesting subjects to me, and if I harp upon the subject it is because I want to impress upon you its value to a foundryman. It is one of the most important things that we have to discuss. There are a great many papers on a great many subjects that are exceedingly interesting, but nothing that is so essential to the foundryman to know as what he is handling. If you have a correct knowledge of the metalloids used in making castings, you will know how to make them. This question is something that we cannot get through with in an evening like this. I am exceedingly anxious to have every foundryman who has had practical experience to take that part which he is most familiar with and investigate it thoroughly and make something of it. We must come here and contribute something of our own personal experience. This matter of one man reading a paper on this and another man reading a paper on that and these papers being enjoyed and then dropped is not right. We men want something in return. I want your thoughts and ideas on the same subject. I expect a very generous criticism on my

paper, and in that way we can get at something that is of value to us.

#### DISCUSSION.

Mr. Ferguson: Gentlemen, I believe that you will all agree with me that this is one of the most valuable papers that has ever been presented to this association, and I regret that the proof sheets were not gotten out earlier so that every one could have had a copy before coming here to-night. It is a paper that will take study to create any amount of discussion. I hope that the members will enter into the discussion as thoroughly as they can under the circumstances.

Mr. Sorge: I would like to ask Maj. McDowell what he means in table B under "Fluidity," the fourth and fifth items: "Edges rounded off; corners of  $\frac{1}{8}$  wasted—not full. Surface rough." "Half of the  $\frac{1}{8}$  and  $\frac{1}{4}$  of  $\frac{1}{4}$  wasted. Castings not run full?"

Maj. McDowell: I referred to the two drawings here showing fluidity. That means that it did not flow into it all, that  $\frac{1}{8}$  part was wasted there. That the metal was not fluid enough to flow further and make a casting as thin as that. In the first casting the edges and corners were full and sharp, and smooth surface similar to the soft casting. Test bars are things of personal property, I was going to say. The foundrymen's associations never established any series of test bars for their own purpose, and each man has a test bar for his own purpose. I have gone over a variety of test bars. This answers its purpose so far as I am concerned. There is a series of test bars that will give you the entire history of any casting you make. If you make these different tests you will know just exactly what made that peculiar sort of a casting. There is a standard transverse and tensile strength, that is the chill block, an indispensable thing in every foundry.

Mr. Ferguson: You say, "It is one thing to make a high-grade strong casting, having a tensile strength of from 35,000 pounds to 40,000 pounds per square inch, and quite another thing

to make a water pipe out of the same metal. It is possible to make cast iron water pipe that will carry over 30,000 pounds tensile strength per square inch, but the combination of metalloids would be different in each kind of casting." Now I do not quite understand that. To my idea it is possible to produce a water pipe of any given thickness that will show a transverse strength of 30,000 pounds on an inch bar. It seems to me that it is altogether due to the handling of the metalloids in due proportion; and if we cannot do this it seems to me it is a lack of knowledge of these metalloids to produce the desired strength of the bar.

Maj. McDowell: I never had experience in making water pipes, and I went to a large concern under a contract to make water pipes that would stand a high tensile strength, and I saw it was a very different thing than to make other things. I could not make a water pipe in the same way as I had made other castings. I had to ascertain what that was. After a series of heats I got what was wanted to make a strong iron. I had to get at the value of the metalloids that made the pipe. There are limitations in making castings in a cupola for certain purposes, and when persons speak of doing wonderful things with a cupola it always strikes me as though they did not know what they were talking about, for a cupola has its limitations. We only get out of it what we put in with some slight losses or additions. When you think that a very small percentage of a certain ingredient will make such a change it is wonderful. If you will look at the table of these three heats, No. 1 is 1.92 silicon, .80 phosphorus, .81 sulphur and .43 manganese. We made a pipe that was sufficiently strong, but not up to contract. We were very much pleased with it. In the next lot we made a stronger material, but the heads pulled off and we did not make a pipe. But in the experience of the two heats we arrived at what we wanted, and you will find in the last heat what did it. There are three different heats and the slight variation, if you will notice, is simply this: That the manganese is increased and the sulphur reduced and the silicon very much lower in this case than in either of the others. We got strength by low silicon and did not have sulphur to contend with.

Mr. Ferguson: I think the initial point in this paper and the point that ought to be studied is the one about the value of metalloids and becoming acquainted with them. That the per cent of iron in the original metal pig is 93.37, leaving 6.63 per cent of metalloids to work with in making castings. To my mind that is a great thought. That that slight percentage is the governing element in all grades of cast iron from the hardest to the softest, from the weakest to the strongest, and the thought comes to me, what a delicate thing it is, and how we went along for years accomplishing what we have accomplished without the proper knowledge for the handling of these things.

Maj. McDowell: If you will look at the next table B and take the first heat of 49,000 pounds. Look it all through. What is it that produced that? Then look at the others. See the slight variation. I have made up a table on the value of wrought iron castings, steel castings and four or five different grades, of their market value, tensile strength and chemical constituents. Look at the differences in iron, some selling for \$45 a ton and others at \$25. We deal with such small amounts in such large things. When I think of it I am perfectly astonished. What foundrymen know and do not know; how they do it and sometimes wish they did know. What we want to do to-day is to get to the point that we do know how we do it. If it is merely a question of metalloids combined with iron. We talk over the dollar and cent question as if that was the almighty thing, when we have to deal with ideas and thoughts. They have more value than dollars; without them dollars would not do much. The idea is crystallized in the mind of the draftsman and then the patternmaker gives the form to it, and the molder makes it, and the furnaceman casts it, and that is the foundation for some great structure, and this small matter of metalloids either makes or mars the entire thing. It is possible for a person with a correct knowledge of metalloids to work from an absolute standpoint to a certain thing. I do not hesitate to go into a foundry and make a thing desired, and I will guarantee that it will be right. There was a time that I could not do this. What we want to do is to arrive at the point that we will



make what we start out to make. The time is coming when iron will be handled more intelligently than it is to-day, and it will be far more satisfactory to both buyer and seller. Just as soon as it comes to the knowledge of the furnaceman that he is selling iron that is worth a great deal more than he is getting for it, he will quit it. And when he does that the foundryman will buy the iron he wants for a certain piece of work.

Mr. Sorge: In the paragraph that our chairman cited you seem to make a positive statement that "The per cent of iron in the original pig metal is 93.37, leaving 6.63 per cent of metalloids to work with in making castings." Did you not really mean that in some iron you find that percentage? Does not that percentage vary in the various irons?

Maj. McDowell: There is no question about that. I was very positive only about that one pig.

Mr. Smith: I take it that the paper is on the value of metalloids and this is a question of great moment to the foundrymen. The great question has always been how to obtain the knowledge. We have not had the advantage of a college education, nor of a chemical education, we simply have to pick it up from books and other writings on the subject. Encyclopedias really give us no knowledge; neither are there any works that take up the entire subject. I believe there is more in this paper of Maj. McDowell's than anything I have ever run across. The only way that we can obtain that knowledge is by discussion and I would like to ask one or two questions. There are several statements made in regard to carbon. In one place it says, "While the second heat was drawn earlier, and therefore it is claimed had more carbon." "It was not for the lack of carbon, but for the want of silicon." A little later on, near the bottom of that column, it says: "In the subsequent heat, No. 5, it fell to .10, and in No. 6 to .09 $\frac{3}{4}$  inches, the carbon remaining the same, but the silicon going down, showing it is want of silicon and not carbon that reduces the elasticity of iron." I would like to ask Maj. McDowell if he considers, as I have read it in the past, that carbon

gives the iron its structure and the other metalloids control that structure. What effect do the other metalloids have upon the carbon?

Maj. McDowell: A casting depends upon the amount of carbon and its relation to the iron. Silicon does not combine, and manganese combines the carbon. Manganese when put into the cupola intensifies the iron's affinity for carbon. When you have those two metalloids occupying such a relation to each other as to affect the casting you are going to make so that two-thirds will be combined and one-third graphitic, you have one kind of iron. In table B in the first heat you will see silicon 1.34, manganese 1.00. Now as far as I know those two elements worked in harmony just to the point to give the strongest metal we could get. I made quite a large number of heats where it runs up to 49,000. I have a list of heats at home where it averages 42,000 pounds tensile strength. The object is to get these two metalloids so that the carbon's relation to the iron is such that a certain amount of carbon is combined and a certain amount becomes graphitic. One-third combined and two-thirds graphitic is a fine iron.

Mr. Ferguson: The Major's statement about manganese assisting in the combination of carbon is at variance with my experience. I will cite you to analyses with hard iron: The first is—Silicon .40, manganese .33, sulphur .09, combined carbon 1.10. The second—Silicon .44, manganese .40, sulphur .07, combined carbon .83.

Maj. McDowell: I do not understand where the silicon and manganese was in the two heats.

Mr. Ferguson: The manganese was put in the ladle.

Maj. McDowell: There is a difference between manganese in the ladle and manganese in the cupola. Manganese at a certain point will make graphitic carbon and manganese at another point will make combined carbon.

Mr. Ferguson: We put the manganese in the ladle as we could control it better. I carried on a line of experiments raising the manganese until it reached 1.38, and up to that time we

found it a softener, it reduced the combined carbon; beyond that point it became a hardener.

Maj. McDowell: When you put manganese into a cupola its action is very different from when it is placed in the ladle. You will get a different effect from it. You will find that silicon does not make itself manifest until it is at a certain point. What we want to find out is that point.

Mr. Ferguson: The point I make is, that I think you should modify the statement that manganese produces combined carbon. It does not up to 1.38. What would you think of an analysis of this kind: Silicon 1.40, manganese 1.26 and sulphur .08, or lower than that, .04, and combined carbon .60?

Maj. McDowell: I never figure on combined carbon alone, I figure on the total amount of carbon. You could give me any number of heats that would puzzle me. I have been very much deceived in putting manganese in the ladle. I would like to say that you will all give me a fair chance to answer questions if you will write them and send them to Mr. Sorge, and I will make a study of them, in advance of next meeting.

Mr. Ott: I would like to ask Maj. McDowell if he has ever run more than one test bar out of the same ladle?

Maj. McDowell: We always make four test bars. We take an average of the four.

Mr. Ott: Can you explain the difference in the four bars?

Maj. McDowell: I cannot. A test bar is simply a guide. I make test bars for transverse strength and I make chill blocks. We made some test bars four feet long and we found difference in the same bar. Then we made a cylinder and cut out from the cylinder a square chunk. That is the government's way of doing it, because they use the iron for shells.

Mr. McPharren: I made a few notes on the train coming down, but I did not understand the scope of the paper. The discussion of the influence of metalloids brings up the old controversy between those in favor of physical tests only and those

who prefer chemical analysis. In this controversy one point has never been clearly enough defined. That is: What is meant by a chemical analysis? The average man gets the silicon and sulphur determined on a sample of pig iron; then, calling that an analysis, makes up his mixture accordingly. He entirely overlooks the fact that silicon and sulphur are but two of perhaps ten to twenty elements. Carbon, phosphorus, silicon, sulphur, manganese, copper, chromium, tungsten, titanium, niobium, nickel, cobalt, aluminum, potassium, sodium, magnesium, and carbon-monoxide have all been found more or less frequently and in varying quantities. The last five probably occur in the inclosed slag. Most of these are of rare occurrence. Even when present in small amounts, some, as titanium and tungsten, exert a powerful influence. The pressure of nitrogen is held by some to account for the inferiority of Bessemer to crucible steel. Nor are our troubles over when we have present but carbon, silicon, sulphur, phosphorus and manganese. Carbon is found in steel in three or four conditions, depending on the amount of carbon present and the previous treatment of the material. Phosphorus is known to exist in two conditions, one producing cold shortness, the other but little effect. I run over these items hastily and do so merely to show why it is that so many things happen that we cannot explain by the ordinary chemical analysis. There is no reason why two irons of exactly the same composition should not be alike. There is a reason for every difference. The chemistry of iron and steel has by no means attained perfection, but our knowledge of the subject is growing each year. The tensile strength of rolled O. H. steel plates can even now be calculated to within a few thousand pounds, and I believe the time will come when the strength, hardness and other properties of iron can be closely calculated from the chemical analysis.

Mr. Carver: As I stated to a few gentlemen before the opening of the meeting, this is by far too important a paper to let it drop as it is. As we have so few of our members present, I want to hear this paper read at a future meeting, and I think with the combined efforts of the individual members and the officers

that the presence of at least two hundred foundrymen can be obtained. I move that the further discussion of this paper at the present time be dispensed with, and to make it a special order of business that there is further discussion of this paper at the next meeting of the Western Foundrymen's Association.

This motion was unanimously carried.

On motion, duly carried, a vote of thanks was tendered Maj. McDowell for his able paper and his presence at the meeting.

## PROCEEDINGS OF THE PITTSBURG FOUNDRYMEN'S ASSOCIATION.

At the January meeting of this Association Thos. D. West presented two papers, which we give below:

### "OXIDATION OF FOUNDRY METALS."

The amount of iron lost by melting is as important an item to study in these days of sharp competition, as that of any other material necessarily destroyed in the making of castings. Many founders endeavor to keep a close record of such losses; but there are many that cannot. Founders that can clean up every day's "heat" of castings and collect in all fine shot, scrap and gates daily, are in the best position to attain the greatest accuracy in such records. Take shops that have castings lying in the sand from one to six days or more before they can be removed or cleaned up, they find the task a much more difficult one. Shops of this latter type may endeavor, every six months or year, to average their total losses of the different irons used; but apart from their inability to know what the loss on any special iron or scrap may be, they cannot feel thoroughly confident in the correctness of their total losses. Shop tools are cast almost daily for themselves, and to make any attempt at keeping their weights would be costly. And, again, more or less fine scrap gets buried up or carried away in such shops.

Did pig and scrap iron always come clean to the founder's yard, then shops not in a position to have confidence in their own records could often be fairly guided by what they could learn of others better placed to collect reliable data.

In buying pig iron the furnacemen allow us 268 pounds per ton for scale and sand. How much of this 268 pounds is actual refuse no one can determine accurately. Thus another obstacle arises. When I first learned that there was a strong possibility of chilled or sandless pig replacing sand-cast pig, one of the first thoughts that came to my mind was that the founder would at least be placed in a better position to know what iron he was ac-

tually receiving from the furnace, or in other words, what percentage of the weight charged to him was actual sand or iron.

In first studying up the casting of pig metal in chills, I could not see anything unfavorable to the universal adoption by foundrymen and steel makers of metal so cast. To make sure, I commenced a series of experiments, in which I was kindly assisted by Dr. R. Moldenke. The result of these researches I gave in a paper before the Western Foundrymen's Association at its fall meeting in Cincinnati, October 18, 1897. At that time I thought I had weighed everything necessary to be considered in adopting chilled pig. At your last meeting, January 3, 1898, it was made evident that there was one point I had not gone thoroughly into, and that was the question of oxidation. Mr. Howard M. Hooker made the claim that a greater loss would be incurred by the use of chilled or sandless pig than by that having sand scale on it, which was said to afford a protection to the iron against oxidation, or being burned away while being brought to a liquid state. I might have followed this point when conducting the series of experiments cited in my Cincinnati paper, and no doubt would have done so had it occurred to me then that the question of oxidation would be raised against the use of chilled or sandless pig. I have no knowledge of the process by which Mr. Hooker has arrived at his conclusions; I can only say that to obtain definite proof that more iron is lost by using chilled than sand-coated pig metal steps that differ from general practice are necessary. Realizing this, I have made a series of original tests embodying 16 "heats" in the twin-shaft cupola which I showed in a paper before this association June 28, 1897, the design of which most of you will remember.

In making the comparative oxidation tests shown in Tables 1, 3 and 4, much care was necessary in preparing the cupola and collecting its refuse. In getting this cupola ready for a "heat," both departments were picked out and daubed up smoothly and then blacked over with graphitic or lead blacking. Such a plan insured that no iron stuck to the sides from the preceding "heats," to be melted down with or change the irons obtained from the



respective sides. The bottom was not dropped after "heats," as in ordinary practice, but after the cupola had cooled down the

TABLE 1. COMPARATIVE OXIDATION TESTS OF PROTECTED AND UNPROTECTED IRON SURFACES.

Kind of metal charged.	Heat No. 1.	Heat No. 2.	Heat No. 3.	Heat No. 4.	Heat No. 5.	Heat No. 6.	Heat No. 7.	Heat No. 8.
	Sand and Chill rolls.	Sand and Chill rolls.	Chill rolls.	Chill rolls.	Chill rolls.	Chill rolls.	Chill rolls.	Chill rolls.
Kind of protection used on coated rolls	Sand scale.	Sand scale.	Lead wash.	Lead wash.	Lime wash.	Lime wash.	Sil. soda.	Sil. soda.
Weight of unprotected and protected charges.....	114 lbs.	80 lbs.	84 lbs.	54 lbs.	81 lbs.	85 lbs.	78 lbs.	90 lbs.
Blast put on.....	3.36	3.18	3.47	2.20	3.17	2.54	3.04	3.43
Protected iron running .....	3.44%	3.27%	3.53%	2.27	3.25	3.00%	3.09%	3.52%
Unprotected iron running .....	3.43	3.25	3.52%	2.26	3.23%	3.00	3.09	3.52
Protected iron all down .....	4.03%	3.40	4.03%	2.34%	3.37%	3.11%	3.20	4.07%
Unprotected iron all down .....	4.01	3.37%	4.02	2.33%	3.37	3.11%	3.19%	4.06
Weight of protected iron obtained.	108 lbs.	75 lbs.	81 lbs.	52 lbs.	77 lbs.	81 lbs.	75 lbs.	87 lbs.
Weight of unprotected iron obtained.	110 lbs.	77 lbs.	81 lbs.	52 lbs.	78 lbs.	81 lbs.	75 lbs.	87 lbs.
Loss of protected iron .....	2 oz.	2 oz.	1 oz.	3 oz.	3 oz.	14 oz.	12 oz.	6 oz.
Loss of unprotected iron .....	13 oz.	14 oz.	15 oz.	15 oz.	3 oz.	1 oz.	5 oz.	8 oz.
Loss of unprotected iron .....	3 lbs.	2 lbs.	2 lbs.	1 lb.	3 lbs.	3 lbs.	2 lbs.	2 lbs.
Loss of unprotected iron .....	14 oz.	14 oz.	15 oz.	13 oz.	1 oz.	2 oz.	4 oz.	10 oz.

refuse would be picked out from the top downward by hand, and every particle carefully pounded in a pan to discover any fine shot or pieces of scrap that might exist in the burnt coke, dross or slag remaining in the cupola at the close of a "heat." This was

TABLE 2. COMPARATIVE FUSION TESTS BY IMMERSION OF IRONS SHOWN TABLE 1.

	Heat No. 1.	Heat No. 2.	Heat No. 3.	Heat No. 4.	Heat No. 5.	Heat No. 6.	Heat No. 7.	Heat No. 8.
Time of immersing rolls 2½" diameter.*	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Time of total fusion of sand protected rolls.	4.04%	4.06	4.09½	4.10%	4.06	4.06½	4.04	4.04%
Time of total fusion of unprotected rolls.....	4.03	4.03½	4.02½	4.02%	4.03	4.03%	4.02%	4.03½
Difference in time of melting .....	1¼ m.	2½ m.	7 m.	7½ m.	3 m.	3¼ m.	1¼ m.	1½ m.

\*The time of dipping was changed to the unit of 4.00 shown so as to make the table easier of solution. The relative differences, however, were kept exactly the same as originally found.

then weighed on fine scales. By this plan not a single ounce of metal that remained as such, could escape being found.

Heats Nos. 1 and 2, Table 1, were charged with rolls that were cast from the same ladle, half being made in sand and half in chill molds, such as seen at Fig. 2. The roll castings were after the pattern seen in Fig. 1,—which it may be said was the same form in which the iron was charged in heats Nos. 3, 4, 5, 6, 7 and 8, as well as those shown in Tables 3 and 4, where rolls are cited. The loss from heats Nos. 1 and 2 ran about 5 per cent for the

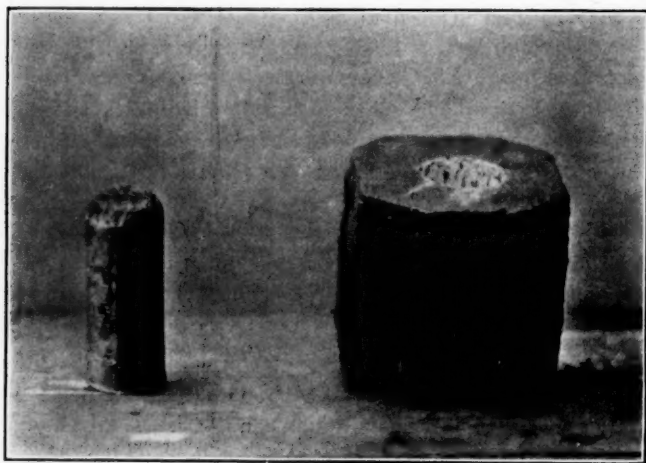


FIG. 1.

FIG. 2.

sand rolls, and 3 per cent for the chilled iron. When these first two heats are compared with those of the chilled iron by the protected and unprotected plan seen in heats Nos. 3 to 8, it will appear how unreliable are the data as to how much sand or scale you are crediting to iron when weighing the charges of sand-coated pig irons. To avoid this uncertainty I adopted the idea of taking gray iron cast in chill molds for both sides of the cupola, coating that for one side heavily with some heat resisting material (by giving each three coats and drying them in an oven after

every coating) and charging the other side with the surface of the chilled or sandless gray iron exposed. By weighing the iron before it was coated I knew exactly what weight of iron was going

TABLE 3. COMPARATIVE OXIDATION TEST OF IRONS CHARGED ON HIGH AND LOW BEDS OF FUEL.

Kind of metal charged.....	Heat No. 9. Chill rolls unprotected.	Heat No. 10. Chill rolls unprotected.	Heat No. 11. Chill rolls coated with lead wash.	Heat No. 12. Chill rolls coated with lead wash.
Weight of charges each side.....	64 lbs.	73 lbs.	75 lbs.	100 lbs.
Blast on .....	3.55	4.27	3.42	3.33
High bed running.....	4.02	4.38	3.50	3.45
Low bed running .....	4.00	4.33½	3.47¾	3.39
High bed all down.....	4.11½	4.48	4.03½	4.05
Low bed all down.....	4.08	4.44	4.56½	3.55
Weight of iron obtained from high bed.....	62 lbs. 6 oz.	70 lbs. 7 oz.	72 lbs. 9 oz.	96 lbs. 12 oz.
Weight of iron obtained from low bed.....	62 lbs. 10 oz.	70 lbs. 8 oz.	72 lbs. 14 oz.	96 lbs. 14 oz.
Loss of iron from high bed.....	1 lb. 10 oz.	2 lbs. 9 oz.	2 lbs. 7 oz.	3 lbs. 4 oz.
Loss of iron from low bed.....	1 lb. 6 oz.	2 lbs. 8 oz.	2 lbs. 2 oz.	3 lbs. 2 oz.

into the respective sides of the cupola. In reality I consider this the only true way of making a comparison between chill and sand-cast pig metals to judge whether scale or sand prevents a loss of iron by oxidation. For heats Nos. 3, 4, 5, 6, 7 and 8 all chilled gray irons were used, the only difference being that I used different materials for coating or protecting the surface of the chill or sandless pig rolls which were to be charged as protected irons. Of the three coatings used, lead wash, wet with molasses water, lime wash, which was hardened with salt, and silicate of soda, the lead wash afforded the best protection, which is proven by the less time required by unprotected chills to start and end in melting than the chill or sandless pig rolls having their surfaces protected or coated with the lead wash. A study of Table 1 would lead us to conclude that there is no practical difference, on the average, in the loss of clean iron, or chilled sandless pig metal, whether protected by a coating of heat resisting material or not.

Believing an immersion test would furnish a good check on the action of the different protectors, lead, lime and silicate of soda, I cast and prepared two rolls from each heat, coating one and leaving the surface of the other bare, connecting the two for immersion in liquid iron by a rod M after the plan seen in Figs. 3 and 4, illustrated in the companion paper on "Effects of Phosphorus on the Fusibility and Strength of Iron," also presented

TABLE 4. COMPARATIVE OXIDATION TEST OF STOVE PLATE AND HEAVY IRON.

	Heat No. 13.	Heat No. 14.	Heat No. 15.	Heat No. 16.
	Stove plate and rolls.	Stove plate and rolls.	$\frac{3}{8}$ -inch plate and rolls.	$\frac{3}{8}$ -inch plate and rolls.
Kind of metal charged.....				
Weight of charge each side.....	100 lbs.	65 lbs.	100 lbs.	65 lbs.
Blast on .....	3.34	3.06	2.20	3.11
Heavy iron running.....	3.39½	3.12	2.25	3.16¼
Plate running .....	3.35½	3.07¼	2.23½	3.15
Heavy iron all down.....	3.54	3.21	2.35	3.22½
Plate all down.....	3.44	3.13	2.33	3.21
Weight of heavy iron obtained.....	96 lbs.	62 lbs.	97 lbs.	63 lbs.
	15 oz.	11 oz.	2 oz.	1 oz.
Weight of plate obtained.....	89 lbs.	57 lbs.	94 lbs.	61 lbs.
	14 oz.	9 oz.	5 oz.	11 oz.
Loss of heavy iron.....	3 lbs.	2 lbs.	2 lbs.	1 lb.
	1 oz.	5 oz.	14 oz.	15 oz.
Loss of plate.....	10 lbs.	7 lbs.	5 lbs.	3 lbs.
	2 oz.	7 oz.	11 oz.	5 oz.

this evening. By a study of Table 2, you will perceive that the sandless rolls coated with lead best resisted fusion by immersion, as well as the heat of melting in the cupola. In fact, all the immersion tests made coincided very closely with the results found by the twin shaft cupola experiments and strongly confirm the conclusions drawn above from Table 1.

TABLE 5. ANALYSIS OF SILICON AND MANGANESE IN LOW AND HIGH BED IRONS.

	Heat No. 10.		Heat No. 11.	
	Silicon.	Man.	Silicon.	Man.
Height of bed, low side.....	1.41	.34	1.46	.38
Height of bed, high side.....	1.36	.31	1.41	.32
Difference .....	.05	.03	.05	.06

After completing the tests illustrated in Tables 1 and 2, I thought it desirable to learn what difference, if any, high and low

beds of fuel might cause in losses of iron. By referring to Table 3 it will be seen that tests Nos. 9 and 10 were heats having the gray chill pig rolls charged without any coating, whereas heats Nos. 11 and 12 had the surface of the iron protected with a wash of lead blacking. In all these four heats it will be seen that the loss was slightly greater with the iron charged on the high bed or that side using the most fuel. While this is true, it is to be said that more fine shot and scrap was found in the side having the low bed. In general practice, the chances are that the majority of founders would not go to the labor and expense of endeavoring to collect all this fine shot and scrap so closely as was done with these tests. Hence the loss of iron to be experienced in actual practice can be reckoned as the greatest with founders aiming to economize fuel in an extreme measure, thereby not procuring good hot iron. All experienced founders know that high beds of fuel give hotter iron, but that it melts slower than iron charged on low beds. The difference in the heights of bed coke used in the experiments of this paper was about 12 inches.

The four heats seen in Table 3 having been completed, I next tested stove plate iron in comparison with the sandless roll iron

TABLE 6. ANALYSES OF IRON IN SLAG FROM LOW AND HIGH BEDS, STOVE PLATE AND HEAVY IRONS.

	Per cent of iron in slag. Heat No. 10.	Kind of iron.	Per cent of iron in slag. Heat No. 13.	Per cent of iron in slag. Heat No. 14.
Height of bed, low side.....	31.39	Heavy iron	25.13	26.78
Height of bed, high side.....	24.06	Stove plate	23.56	16.97
Difference .....	7.33		1.57	9.81

as used in previous heats. In selecting the stove plate, I secured it as clean as I could, picking it out from the scrap pile. Notwithstanding this, its loss will be seen, by referring to Table 4, tests 13 and 14, to exceed by about 7 per cent that of the more solid heavy iron used in comparison with it.

After testing the stove plate referred to, I then ran two heats having a plate casting  $\frac{3}{4}$  inches thick, broken in pieces about 4

inches square, and cast it in comparison with the rolls or heavier iron, as seen in tests 15 and 16. This  $\frac{3}{4}$ -inch plate iron was cast especially for the purpose and used the day following, so that it was perfectly free of all rust or dirt scale, its coat being only that of the film of oxide formed on its surface while in the green sand mold. The loss of this  $\frac{3}{4}$ -inch plate will be seen to be about 5 per cent, and this can be taken as a good test for this character of flat-faced surfaces when charged in the form of clean scrap, not exceeding 1 inch in thickness.

It will be well to state that the iron used for pouring the chilled or sandless gray roll bodies used throughout all the heats herein described (form shown in Fig. 1) were taken from one of our regular shop cupola heats and would average about 1.70 silicon, .045 sulphur, .50 manganese and .10 phosphorus. Owing to this iron being moderately high in silicon and fairly low in sulphur, it would only chill to a depth of about  $\frac{1}{4}$  inch in the small rolls shown. Such a depth of chill on the surface of the rolls used for the heats herein described, would agree fairly well with that found in general gray pig irons that had been cast in chills instead of sand molds, and I believe all will concede it to be an iron well suited for tests on the comparative oxidation of chilled and sand-cast pig metal.

Since writing the above article, I have received analyses from Dr. R. Moldenke which, as shown in Tables 5 and 6, will prove a very interesting study. Table 5 would show that greater silicon and manganese was lost on the high beds than the low beds of fuel. Another interesting point, which may surprise many, is that the slag which came from the stove plate iron has a less percentage of iron in it than that which came from the heavier or sandless gray roll iron. While this is shown as such, it does not imply that there is a less total loss of iron with stove plate than heavier iron, as we know by actual practice the reverse to be true. The greater loss of iron by remelting stove plate than is found in heavier irons, is due to the films of oxide or scales of rust and dirt, which, when attacked by the high temperatures of a cupola, etc., in blast, either go to make extra slag

or escape out of the stack in other forms. This phenomena in extra slag production is exhibited in actual practice whenever we melt dirty or burnt iron, as all founders well know.

The facts presented herewith suggest that opinions of the past in regard to oxidation of metal are in many cases not well founded, and that where losses of iron have been attributed to oxidation of the metallic iron proper, or a reduction of the metalloids, proper account has not been taken of the dirt, rust or films of oxide that might have coated the pig or scrap iron used. We are led to conclude that if it were possible for us to secure clean iron, free of all sand, rust or scales, or oxide of iron, the loss of metallic iron due to oxidation proper, is not as large as has been generally supposed.

#### EFFECTS OF PHOSPHORUS ON THE STRENGTH AND FUSIBILITY OF IRON.

Since writing my second paper on the comparative fusibility of foundry metals, I have been experimenting on the effects of adding phosphorus to iron, to learn what changes were thus

TABLE 1. COMPARATIVE TENSILE TESTS WITH PHOSPHORUS ADDITIONS.

TESTED BY DR. R. MOLDENKE							
	Analyses	No.	Ultimate	Ultimate			
	Letter.	Test.	Area.	strength.	strength	Av'ge.	
1st Cast Phosphorus addition.	A	1	1.94	53620	27640	27640	
	A	2	This bar broke with a flaw.				
1st Cast Regular Iron.	B	3	1.77	27010	15260	15130	
	B	4	1.77	26530	15000		
2nd Cast Phosphorus addition.	C	5	1.09	27400	25140	23790	
	C	6	1.09	26090	23840		
	C	7	This bar broke with a flaw.				
	C	8	1.06	24260	22390		
	D	9	1.07	18730	17500		
2nd Cast Regular Iron.	D	10	1.07	19430	18160	17617	
	D	11	1.09	18550	17330		
	D	12	1.09	18700			
	E	13	1.09	29810	27350		
3rd Cast Phosphorus addition.	E	14	1.09	27450	25190	26070	
	E	15	1.09	29600	27160		
	E	16	1.09	26300	24600		
	F	17	1.09	19580	17970		
3rd Cast Regular Iron.	F	18	1.09	18100	16610	16890	
	F	19	1.11	18720	16870		
	F	20	1.11	17891	16120		



caused in the strength and fusibility of iron. Some important discoveries have resulted, which briefly stated are that adding phosphorus to Bessemer iron by my plan increased its strength from 25 to 75 per cent, as can be seen by tests Nos. 1, 5, 13, 21, 23 and 27, Tables Nos. 1 and 2. I have also found that the addition of phosphorus greatly increases the fusibility of solid iron, as is to be seen by Table 4. What will be the effect of adding phosphorus to iron having that element higher than .10, the limit of standard Bessemer, I have yet to determine.

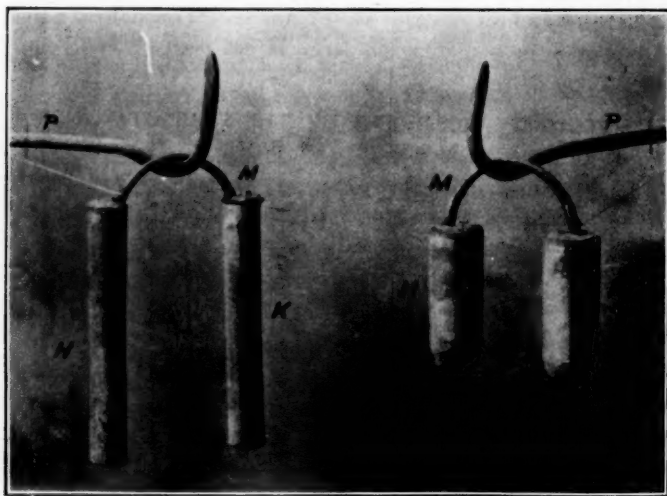


FIG. 3.

FIG. 4.

In making these phosphorus experiments I used two ladles, one holding about 200 pounds of iron and the other 35 pounds. The metal was caught in the large ladle at the cupola and when carried to the molds about 30 pounds was poured out of it into the small ladle, in which sticks of phosphorus had been placed before pouring in the metal. The mixture was then stirred with a small rod as long as the fluidity would permit, it being not too dull to pour the test bars properly. Phosphorus is conceded to

add fluidity to metal, but this method of adding it to iron causes the latter to solidify rapidly—an opposite effect to that found in using pig irons in which the phosphorus runs well up.

After the test bars had all been cast, I forwarded them to Dr. R. Moldenke, the well-known metallurgist of the McConway &

TABLE 2. COMPARATIVE TRANSVERSE TEST WITH PHOSPHORUS ADDITIONS.

	Analyses	No. of			
	Letter.	Test.	Dia.	Deflection.	Load.
1st Cast, Phosphorus addition.....	A	21	1.57	.125	8220
1st Cast, Regular Iron.....	B	22	1.50	.08	4180
2nd Cast, Phosphorus addition.....	C	23	1.16	.155	3632
	C	24	1.16	.145	3400
2nd Cast, Regular Iron.....	D	25	1.18	.12	2430
	D	26	1.18	.12	2080
3rd Cast, Phosphorus Iron.....	E	27	1.18	.115	3430
	E	28	1.18	.17	3318
3rd Cast, Regular Iron.....	F	29	1.19	.09	2630
	F	30	1.19	.122	2188

Torley Co., Pittsburg, who kindly tested them for their tensile and transverse strengths as given in Tables Nos. 1 and 2. He also furnished the analyses of their casts as seen in Table 3. For the first cast, Tables 1 and 2, I made two bars about  $1\frac{1}{2}$  inch diameter, cast on end, one of which was poured from the regular cupola metal and one after the phosphorus was added. For the next two

TABLE 3. CHEMICAL ANALYSES OF TEST BARS IN TABLES 1 AND 2.

	1st Cast.		2nd Cast.		3rd Cast.	
Letter.....	A	B	C	D	E	F
Phosphorus .....	.161	.088	.136	.095	.173	.093
Silicon .....	1.48	1.53	1.46	1.48	1.32	1.37
Manganese .....	.65	.68	.58	.60	.63	.65
Sulphur .....	.03	.03	.03	.03	.03	.03
Graphitic Carbon .....	2.10	2.90	1.80	2.48	1.84	2.66
Combined Carbon .....	1.85	1.20	2.44	1.84	2.19	1.50
Total Carbon .....	3.95	4.10	4.24	4.32	4.03	4.16

casts, I used  $1\frac{1}{2}$  inch round bars so as to obtain a greater number which, as will be seen, had four bars for each cast, two being of the regular metal, and two having the phosphorus added to them. All of the bars were cast on end, so as to aid in securing solidity and uniformity in texture.

A remarkable feature of these tests is the phenomenal increase in strength that a slight addition of phosphorus makes. I know of none having demonstrated heretofore the effects of phosphorus in so greatly increasing the strength of iron as shown by the tests herein exhibited. I feel all will be interested in this line of research, which I shall follow up in other ways and report my findings from time to time as the work progresses.

As founders, we have very vague knowledge up to the present time of what combinations in the metalloids are the best in cast iron to protect it against the action of heat or fire. As an example, we often find inquiries being made as to what kind of iron is best for the manufacture of such castings, as annealing boxes, pots, grate bars and the like. I have started investigation in this line and present Table 4 to show the effects of phosphorus on fusibility, when immersed in liquid iron. By a study of this table, it will be seen that the high phosphorus irons melted away first. The plan I originated to make the test shown in Table 4 is exhibited

TABLE 4. COMPARATIVE FUSION TEST BY IMMERSION OF BARS NOTED IN TABLES 1 AND 2.

Diameter of Rolls.	1st Cast.		2nd Cast.		3rd Cast.	
	1½ ins.	2¾ ins.	1½ ins.	2¾ ins.	1½ ins.	2¾ ins.
Time of Dipping.....	2:00	3:00	2:00	3:00	2:00	3:00
Time of total fusion lower phosphorus bars .....	2:03½	3:04¾	2:03	3:04¾	2:03¾	3:05
Time of total fusion higher phosphorus bars .....	2:02½	3:03½	2:02¾	3:03¾	2:02	3:03½
Difference in time of melting.	1 min.	1¼ min.	¾ min.	1¼ min.	1 min.	1½ min.

by Figs. 3 and 4, which display two sizes of fusing test specimens. At H and K, Fig. 3, are bars 1½ inch diameter by 12 inches long, connected by a rod M. H and K, Fig. 4, are test specimens 2 3-8 inches diameter by 6 inches long. In casting these test specimens, one was poured with the regular cupola metal, and the other with the metal after the phosphorus had been added in the manner described. By using a hook as at P, Figs. 3 and 4, to let these test specimens sink into a ladle of molten metal, it will be readily seen that both bodies H and K must be subjected to exactly the same conditions of heat, etc., in testing their fusibility. By such a plan, if H melts down before K, we have positive proof that H pos-

sesses a lower fusing point than K. I find this one of the simplest and most inexpensive plans to test the fusion of mixtures, or the effect of any one of the metalloids on the fusibility of iron.

At the conclusion of the reading of the papers, Mr. West explained in more detail his experiments and Dr. Moldenke the tests and analyses, and both were asked questions on points touched in the papers.

Mr. Friend inquired whether sulphur would not be increased in a chilled pig, his opinion being that sand might protect the iron before melting.

Mr. Metcalf made the observation that melting down a chilled roll always seemed to give more slag than a sand roll.

Mr. Uehling maintained that the added strength of the test bar, as cited in the second paper, was brought about by the changing of some of the graphitic to combined carbon uniformly throughout the bar, whereas mechanical means of bringing about this change would affect only the outer portion. Hence, strains usually found as a result of mechanical chilling would be wanting. Continuing, Mr. Uehling showed the reliability of Mr. West's experiments on oxidation by presenting the following table of the losses calculated from Mr. West's results:

	Per cent. Ave'ge.
Sand iron loss.....	5.10
Sand iron loss.....	6.09
	—
	11.19 = 5.595
Lime wash loss.....	3.93
Lime wash loss.....	3.60 = 3.765
Graphite wash loss.....	3.49
Graphite wash loss.....	3.36 = 3.425
Sandless iron loss.....	3.40
Sandless iron loss.....	3.54
Sandless iron loss.....	3.49
Sandless iron loss.....	3.47
Sandless iron loss.....	3.78
Sandless iron loss.....	3.68

Sandless iron loss.....	2.88
Sandless iron loss.....	2.92 = 3.395
Soda silicate wash loss.....	2.97
Soda silicate wash loss.....	2.78 = 2.875

This table, it was contended, showed the remarkable accuracy attained with even such small heats. Mr. Uehling further explained the reason why chilled pig would not waste as much as the sand pig. This, he said, was due to the fact that a slight formation of oxide of iron in the case of the sand pig would immediately cause a slagging action, the iron thus being absolutely lost, whereas in a chilled pig the oxide coming in contact with incandescent carbon would be reduced back to iron again. Here also would come the advantage of plenty of fuel to keep the flame as constantly up to the reducing as possible.

## **PROCEEDINGS OF THE NEW ENGLAND FOUNDRYMEN'S ASSOCIATION.**

A large number of the members of this association attended the annual dinner at the United States Hotel, Boston, January 12. The meeting was presided over by the president, George H. Gibby. Walter B. Snow read the paper of the evening, which is given herewith:

### **THE USES OF THE BLOWER IN THE FOUNDRY.**

No device is more vital to the operation of the modern foundry than that by which air, under the requisite pressure, is supplied to the ignited fuel within the cupola. Cupolas may vary in their proportions, and coal, coke and iron in their quality, but under no conditions can successful melting be accomplished without the employment of some device partaking of the nature of a blower. Although most important, this is by no means the sole purpose for which a blower is, or may be, employed in a foundry. Its various uses will be considered as we proceed.

It is not the purpose of this paper, however, to discuss cupola practice and foundry methods, with which you should be most familiar, but rather to present the fundamental principles of the fan blower; to point out its prominent advantages, and, in a general way, to indicate its uses and the general methods of its application.

Under the broad term "blower" may be classed four types of machines, differing widely in their construction and operation.

First. The peripheral discharge fan wheel with enclosing case.

Second. The propeller or disc wheel, discharging its air in lines practically parallel to its axis.

Third. The so-called rotary blower with close fitting revolving propellers, and

Fourth. The blowing engine, acting upon the principle of the plunger pump, and capable of producing pressures of several pounds to the square inch.

Of these four types, the second, or propeller type, is absolutely valueless for cupola work, because of its inability to produce the required air pressure; while the fourth, or blowing engine type, is too complicated and expensive for use in the ordinary foundry.

For all purposes, except blowing cupolas, the fan blower is the only type which is adaptable. Although the rotary blower is to a certain extent employed for this specific purpose, a clear statement regarding the theory and operation of the fan blower, such as it is here attempted to make, should render evident the predominant advantages of the latter type.

According to the purpose for which they are designed, fan blowers may be classed either as volume blowers or pressure blowers, although one type naturally merges into the other. In either type the fan blower, proper, consists in its simplest form of a number of blades extending radially, or nearly so, from its axis and presenting practically flat surfaces to the air as they revolve. By the action of the wheel the air is drawn in axially at the center and delivered from the tips of the blades in a tangential direction. It is therefore designated as a centrifugal fan, or, more properly, as a peripheral discharge fan.

As will appear more clearly in what follows, a volume blower is primarily designed to discharge air in large quantity under low pressure with the minimum expenditure of power. This requires a wide and comparatively slow running wheel. A pressure blower, on the other hand, is designed for the purpose of creating a high pressure, which may be as great as 20 ounces per square inch, while delivering a relatively small volume of air. To this end the wheel must be narrow and operated at high speed.

In operation, the peripheral discharge fan sets in motion the air within it, which, acting by centrifugal force, is delivered tangentially at the outer circumference of the wheel. Air rushes in at the axial inlet to fill the space between the blades, in which there is, by the centrifugal action, a tendency to form a vacuum. The degree of this vacuum is dependent upon the circumferential speed of the wheel; and the velocity of the air discharged through



an outlet of proper size is substantially equal to that of the circumference of the wheel. The fan case thus virtually becomes a reservoir from which the air escapes through the outlet, the proper size of which to produce the above stated results will be discussed farther on.

The velocity with which air escapes into the atmosphere from a reservoir is dependent upon the pressure therein maintained and upon the density of the air. The pressure per unit of area divided by the density per unit of volume gives the head, usually designated as the "head due to the velocity." The velocity produced is that which would result if a body should fall freely through a distance equal to this head. In the case of the flow of water such a head always exists; as, for instance, when a standpipe is employed to produce the requisite pressure. Suppose the head of water to be 50 feet and its weight per cubic foot to be 62.5 pounds, then the pressure per square foot will be  $50 \times 62.5 = 3,125$ , and that per square inch  $3,125 \div 144 = 21.7$  pounds. Its theoretical velocity of flow from an orifice at the bottom of the standpipe would be 56.7 feet per second, as determined by the formula for falling bodies, which is  $v = \sqrt{2gh}$  in which

$v$  = velocity in feet per second.

$g$  = acceleration due to gravity.

$h$  = head in feet, here 50 feet.

In the case of air, however, an actual homogeneous head never exists, but in its stead we have to deal with an ideal head which can only be determined by dividing the pressure by the density. As the density of air is so much less than that of water it is evident that for a given pressure the head will be far greater in the case of air. But the velocity of discharge is dependent only on the distance fallen which is represented by the head, whether real or ideal. As a consequence, air under a stated pressure escapes at vastly higher velocity than water under the same conditions. Calculated in the same manner the velocity of escaping air under a pressure of 21.7 pounds per square inch is 1,626 feet per second. By the employment of formulae based upon this

theory the elaborate basis tables in the Sturtevant catalogues have been calculated.

In the attempt to force air at a given velocity through a given pipe, it is the province of the fan wheel, if employed therefor, to create within the fan case a total pressure above the atmosphere which shall be sufficient to produce the velocity and also overcome the resistance of the case and the pipe. If, however, the pipe be removed and the fan be allowed to discharge the air through a short and properly shaped outlet, the pressure necessary will, with an efficient fan, be substantially that required to produce the velocity. The method of determining the velocity due to any given pressure has just been explained. From the same formulae, properly transposed, the pressure due to any given velocity or necessary to its creation may be determined. The pressure thus determined is properly that which it is the purpose of a fan, employed as a device for moving air, to create.

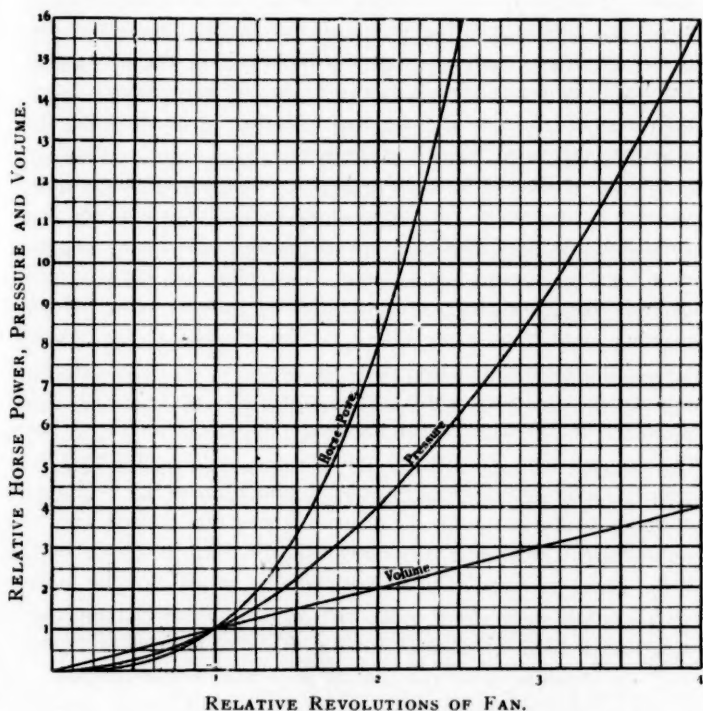
The velocity of the fan tips or circumference of the fan wheel which is necessary to produce a given velocity of flow through a properly shaped outlet within the capacity of the fan, is substantially equal to the velocity of flow. If, therefore, the peripheral velocity of a given fan is known, the resulting pressure for the production of velocity through an outlet of proper size and shape may be readily calculated.

From the basis formula already employed, as well as from the preceding discussion, it is evident that the pressure created by a given fan varies as the square of its speed. That is, doubling the speed increases the pressure fourfold. The volume of air delivered is, however, practically constant per revolution, and therefore is directly proportional to the speed.

The work done by a fan in moving air is represented by the distance through which the total pressure is exerted in a given time. As ordinarily expressed in foot pounds, the work per second would, therefore, be the product of the velocity of the air in feet per second, the pressure in pounds per square foot, and the effective area in square feet over which the pressure is exerted.

From this it is evident that the work done varies as the cube of the velocity, or as the cube of the revolutions of the fan. That

is, eight times the power is required at twice the speed. The reason is evident in the fact that the pressure increases as the square of the velocity, while the velocity itself coincidentally increases; hence, the product of these two factors of the power required is indicated by the cube of the velocity.



The theoretical relations between the revolutions of a fan and the volume, pressure and horse-power are clearly shown by the accompanying diagram.

These curves are based upon the facts that the volume varies directly as the speed, the pressure as the square and the horse-power as the cube of the speed. Thus it is shown by the curves that if the speed is doubled the volume is also doubled, the pres-

sure is increased four times and the horse-power becomes eight times greater. The tremendous power expenditure required for even a moderate increase of speed is thus rendered distinctly evident.

In selecting a fan, the facts just presented should be borne in mind. It appears to be so simple to secure increased volume by running a given fan at higher speed, that the influence upon the power required is frequently overlooked. If the necessary amount of power is actually furnished, its expenditure will entail great loss in efficiency as compared with that required to operate a fan properly proportioned to the work.

In the design of a wheel to meet given requirements it is necessary to make its peripheral speed such as to create the desired pressure, and then to so proportionate its width as to provide for the required air volume. Evidently, the velocity and corresponding pressure may be obtained either with a small wheel running at high speed or a large wheel running at low speed. But, if the diameter of the wheel be taken too small, it may be impossible to adopt a width, within reasonable limits, which will permit of the passage of the necessary amount of air under the desired pressure. Under this condition it will be necessary to run the fan at higher speed in order to obtain the desired volume. But this results in raising the pressure above that desired, and in unnecessarily increasing the power required. On the other hand, if the wheel be made of excessive diameter, it will become more impracticable on account of its narrowness. Between these two extremes a diameter must be intelligently adopted that will give the best proportions for the specific work it is designed to do.

The actual work which a fan may accomplish must depend not only on its proportions, but upon the conditions of its operation and the resistances which are to be overcome. Evidently, it is improper to compare fans when operating under such conditions that these resistances cannot be definitely determined. The simplest and most natural condition of operation is that in which the fan is operated without other resistance than that of the gas; that is, with open inlet and outlet. For proper com-

parison of different fans, the areas through which the air is discharged should bear some constant relation to the dimensions of the wheels themselves.

It has been determined experimentally that a peripheral discharge fan, if enclosed in a case, has the ability, if driven at a certain speed, to maintain the pressure corresponding to its tip velocity over an effective area which is usually denominated the "square inches of blast." This area is the limit of its capacity to maintain the given pressure. If it be increased the pressure will be reduced, but if decreased the pressure will remain the same. As fan housings are usually constructed, this area is considerably less than that of either the regular inlet or outlet. It, therefore, becomes necessary, in comparing fans upon this basis, to provide either the inlet or the outlet with a special temporary orifice of the requisite area and proper shape, and make proper correction for the contracted vein. The fan is thus, in a sense, placed in a condition of restriction of discharge, which it approaches in practice only in so far as the resistance of pipes, passages and material through which the air must pass have the effect of reducing the free inlet or outlet of the fan.

The square inches of blast, or, as it may be termed, the capacity area of a cased fan, may be approximately expressed by

$$\text{Capacity area} = \frac{D W}{x}$$

In which  $D$  = diameter of fan wheel, in inches.

$W$  = width of fan wheel at circumference, in inches.

$x$  = a constant, dependent upon the type of fan and casing.

The value of  $x$  has been very carefully determined by the B. F. Sturtevant Company for different types of fans; but these values must be applied with great discretion, acquired through experience and a thorough knowledge of all the conditions liable to affect the fan in operation. An approximate value of  $x$  for general practice is not far from 3, but this is to be used only to

determine the capacity area over which the given pressure may be maintained. This is not a measure of the area of the casing outlet, which is always larger than the square inches of blast. As a consequence, the pressure is lower and the volume discharged is somewhat greater than would result through an outlet having the square inches of blast for its area. But the maximum pressure may be realized when the sum of the resistances is equivalent to a reduction of effective outlet area to that of the square inches of blast.

Both the volume and the power required will evidently increase with the area of the outlet, being greater with the normal outlet than with that representing the capacity area. But this increase will not be proportional to the area; for the greatest delivery of air and the largest consumption of power will occur when the casing is entirely removed and the fan left to discharge entirely around its periphery.

Although the theoretical considerations which govern the design of fans have here been given, the conditions which exist in any given case must enter into any decision as to the practical dimensions to be given the fan. If volume alone, regardless of pressure, is the requisite, the larger the fan the less the power required. There is a strong temptation, however, for a purchaser to buy a smaller fan and run it at a higher speed; for he sees only the first cost and does not realize the entailed expenditure for extra power. If possible, a fan should never be made so small that it is necessary to run it above the required pressure in order to deliver the necessary volume. To double the volume under such conditions requires eight times the power; three times the volume demands twenty-seven times the power.

For certain purposes, such as the blowing of cupola furnaces, a comparatively small volume of air is required, but under high pressure. For exhausting, blowing boiler fires, and the like, the volume required is greater and the pressure relatively less. The former wheel requires to be narrow at the circumference, thus providing the escape of only a small amount of air. When a fan is employed for exhausting hot air or gases, the speed required

to maintain a given pressure difference is evidently greater than that necessary when cold air is handled, the difference being due, and inversely proportional, to the absolute temperature.

The preceding discussion, relating as it does to theoretical features of design and operation, has of necessity taken on a somewhat abstruse, and, I also fear, a decidedly uninteresting character. But its presentation has appeared to be desirable because of its importance. We may now turn to the different types of fan blowers employed in the foundry and consider them in a somewhat more practical manner.

First of all is the pressure blower, for blowing the cupola, so familiar to you in the form of the Sturtevant steel pressure blower. The extreme length of the bearings and the special arrangement for keeping them well supplied with oil are among the most important features which have made possible the continued employment of blowers of this make for fully a third of a century with practically, and, in many cases, with absolutely no expense for repairs. The fan wheel is narrow, with tapering sides, reducing to the minimum width at the outer circumference where the air escapes from the wheel into the surrounding case. Numerous curved blades or floats serve, by their continuous action, to prevent the return of this air to the wheel center, and thereby maintain the pressure due to their tip velocity. From what has previously been said, it must be evident that even a slight change in the width of the tip of the blade of such a narrow wheel must have a marked effect upon the volume of air which is discharged and upon the power which is required to accomplish this result. For this reason blowers cannot be compared by the areas of their casing outlets, but only by their capacity areas, as determined by the proportions of the wheels.

The general application of a pressure blower to a cupola is too well known to require description; but certain features which relate to its efficiency may well be considered here. The proportions of a pressure blower wheel should theoretically be such that its capacity area or square inches of blast shall be practically equal to the free area through the fuel and iron in the cupola, less the



influence of the resistances of piping, tuyere boxes, fuel and iron. These resistances are evidently the equivalent of just so much reduction in area, and must therefore enter into any consideration. But it is manifestly true that differences in the length and arrangement of piping in different plants, and of size, quantity and character of the charges in the same plant, introduce such variable conditions that it is impossible to design a blower of any type that shall at all times be just exactly proportioned to the work to be done. For this reason the exact power required to operate any given blower cannot be given as an absolute quantity, but can only be determined when all of the conditions are known.

It is, or at least it should be, customary in specifying the pressure required to operate a cupola, to refer to that in the wind-box. On the other hand, the table of blower speeds presented in the Sturtevant catalogue gives the number of revolutions necessary to produce the given pressure at the fan outlet when its area is within the capacity of the blower. Owing to losses due to transmission, this pressure cannot be maintained at any more or less distant point, such as the wind-box of the cupola, unless the speed of the fan is increased sufficiently to produce an excess of pressure equal to the transmission loss.

It is the failure, on the part of the purchaser, to comprehend this fact, and to make due allowance for transmission losses, that sometimes results in too low a pressure at the cupola, and an unjust charge against the blower. Large, straight and short connections from blower to cupola are always imperative if waste of power is to be avoided. If changes in the direction of the piping are necessary, they should be made with as large a radius of curvature as possible. It should be distinctly understood that the power required to operate a fan blower is proportional to the area of discharge. If this area be reduced to zero, by the closing of the blast gate, the power will be reduced to merely that due to the friction of the machine and of the air confined within the case. Too often it is claimed, by those who ought to know better, that closing the pipe increases the power; but, as power is expended only when air is moved, the fallacy of this statement is evident.

This fact points to one of the prominent economic advantages of the fan blower, viz: its automatic action. Instead of always delivering a fixed volume of air, regardless of requirements, the fan blower automatically increases the volume as the resistances are decreased. On the other hand, if the fan blower be in operation with a fairly free outlet, in excess of its capacity area, and that free area be decreased, the pressure produced by the fan will immediately rise, thus tending at once to overcome the increased resistance. Therefore, if a certain maximum pressure is known to be required in a given cupola, the fan may be so speeded as to give this at such times as the conditions demand; while at other times, when less pressure or volume of air is required in the cupola, proper manipulation of the blast gate will economize power. Compared with a type of blower, like the rotary, in which a certain maximum pressure and volume must always be maintained, and a portion allowed to waste if not required, the economic advantage of the fan blower is evident.

Although it has already been stated that this paper does not attempt to draw comparisons with the rotary blower, it is impossible to make clear certain advantages, such as the above, without considering their relations. This is also true in the consideration of the following points.

In the matter of first cost the fan blower is, for the same capacity, only about one-quarter as expensive as the rotary blower, and weighs on the average only about one-ninth as much. This latter feature is of the greatest importance, particularly in the case of large plants; for with the fan blower expensive foundations and high freight charges are avoided, while the handling of parts for repairs is rendered far easier. In the matter of efficiency under the same conditions, the fan blower has been shown by impartial experiment to be superior, while in general endurance, in lack of danger of breakage and of leakage due to wear, it may be fairly claimed to take the lead.

We may now turn to other uses of the fan blower in the foundry—uses in which it has no practical competitor. Employed as an exhaust fan, and properly designed for its work, it has

found an extended application for removing the dust from tumbling barrels, from emery wheels, and, in fact, for exhausting dust, smoke or objectionable gases from any machine or apartment in which they are generated. For such work the fan is driven at comparatively low speed, and proper connection made to the space or spaces from which the objectionable matter is to be drawn. This passes through the fan and thence to any desired place of deposit and is discharged into the open atmosphere.

In the case of the pattern shop, which usually forms an adjunct of the foundry, a fan of this type in the form of a planing mill exhauster is always of advantage for the removal of shavings and sawdust. The width of the wheel in such a fan is far greater both at inlet and outlet than that of a pressure blower wheel. A large volume of air at comparatively low pressure is thus passed through the fan with a minimum expenditure of power.

A similar type of fan on a larger scale is used in connection with a steam-pipe heater for the heating and ventilation of the model foundry. By the concentration of all of the pipe in a single heater across which large volumes of air are caused to pass, the amount of pipe is reduced to from one-third to one-fifth of that which would be required if it were strung around the foundry, as in the case of direct radiation. This concentration of the heating surface also serves to reduce to a minimum all possibility of freezing, renders the regulation of temperature as simple as is possible, and presents numerous other advantages. The heated air is distributed by means of the fan through a more or less extended system of underground ducts with vertical wall flues or of overhead galvanized-iron piping. The large quantity of air thus supplied secures adequate ventilation, causes all air leakage to be outward and serves to keep the foundry comfortable and clear of gas and steam during the heat, if cool or slightly tempered air be then supplied.

A similar form of apparatus, designed to deliver air at high temperature, may be employed for keeping cores dry. It is also

used for drying flask and pattern lumber, when the quantity is sufficient to warrant the arrangement.

Although the boiler plant in connection with an independent foundry is usually of somewhat limited size, nevertheless, the fact should not be overlooked that the fan blower is rapidly usurping the place of the chimney in the production of draft, or serving as its assistant in securing desired results. Applied to force the air into a closed ash pit it creates a pressure which makes possible a high combustion rate, the burning of cheap fuel, and the attainment of the maximum capacity of the boilers. Employed as an exhauster, through which the gases are drawn, it, in addition, does away with the necessity of a high chimney. Under either form of application perfect control may be maintained over the draft pressure, and it may be automatically increased or decreased coincidently with a slight fall or rise in the steam pressure, which thus remains almost absolutely constant.

Such, then, are some of the uses of the fan blower in the foundry. Either as a convenience or as a necessity it is ever in demand, and its forms of application are constantly increasing. It, therefore, stands to-day as a specific type of machine, whose general advantages and peculiar adaptability are becoming more and more familiar to every manufacturer and engineer.

The annual meeting was also held at the same time and the following named officers were elected: George H. Gibby, of East Boston, president; W. O. Barbour, of Cambridgeport, vice-president; Fred F. Stockwell, of Cambridgeport, secretary; George H. Lincoln, of South Boston, treasurer; F. B. Farnsworth, of New Haven, Conn.; A. P. Baker, of Nashua, N. H.; W. H. Carpenter, of Providence, R. I.; Thos. McDermott, of Biddeford, Me., and W. S. Foster, of Richford, Vt., executive committee.

## **A REVIEW OF THE FOUNDRY LITERATURE OF THE MONTH.**

### **AMERICAN MACHINIST.**

January 6.—L. C. Jewett illustrates a method of molding columns and other castings in the floor, which still retains all the facilities with which the mold may be prepared, when a novel is used. Briefly stated the practice of Mr. Jewett is to place the pattern in a temporary frame and ram up such a portion as may be necessary, after which this frame, together with the pattern, is rolled over and deposited on a previously prepared level bed, when the frame is removed and the molding proceeds as ordinarily.

January 13.—A representative of this journal describes some features of the large plant of the Sessions Foundry Company, at Bristol, Conn. Besides matters of general interest, the article contains an illustrated description of the molding of a large fly-wheel weighing above 30 tons.

R. D. Moore writes of "Molders' Gates," and by the illustration of several examples of these demonstrates why difficulties are sometimes encountered along this line.

### **AMERICAN MANUFACTURER.**

This journal reproduces from the "Colliery Guardian" an article by Walter J. May on "Clean Iron Castings" which we print in full, as the subject is one of general interest to all foundrymen.

#### **Clean Iron Castings.**

Generally speaking two faults are present in many of the ordinary castings—want of homogeneity, and the presence of dirt mechanically mixed with the iron—and these faults as a rule are responsible for more wasters than any other causes for which the molder can be called to account. Usually to secure the best results in castings where a more or less heterogeneous mixture of iron is used, some form of flux is used either in the cupola, receiver or ladle, the object of this being to secure a more perfectly

homogeneous casting, free from dirt, and possibly of increased strength, and preferably the writer selects one of the new forms of ferro sodium for this purpose, as both sound castings and increased strength are shown in numerous tests made for the purpose with various irons. To show how this flux affects iron it is well to give a few test results, remarking at the same time that only the normal shrinkage takes place in the castings, but the grain is altered considerably for the better where strength and density are required. The first three results are from hematite only, and the second three from a mixture of 25 per cent hematite and 75 per cent good foundry pig, the stresses being given in pounds per square inch.

	Ultimate transverse stress.		Ultimate tensile stress.	
	Lb.	Tons.	Lb.	Tons.
1. Unfluxed .....	2,620	1.17	13,641	6.09
2. Fluxed .....	2,755	1.23	19,129	8.54
3. Fluxed .....	2,531	1.13	20,361	9.09
4. Unfluxed .....	3,942	1.76	28,985	12.94
5. Fluxed .....	4,032	1.80	31,404	14.02
6. Fluxed .....	4,054	1.81	30,665	13.69

With tests made by Messrs. D. Kirkaldy & Sons, with bars made from 23 per cent Gartsherrie pig and 77 per cent common foundry scrap, the results are somewhat different, the use of ferro-sodium increasing the transverse strength while reducing the tensile strength somewhat, but this was anticipated and mentioned before the iron was melted. In this case the bars were 2-inch by 1-inch in section and supported on knife edges 3 feet apart for transverse stress, and of the same size and section as the preceding for tensile stress.

	Ultimate transverse stress.		Ultimate tensile stress.	
	Lb.	Deflection inch.	Lb.	
Unfluxed .....	2,904	.35	25,837	
Unfluxed .....	2,808	.34	24,316	
Fluxed .....	3,516	.42	24,792	
Fluxed .....	3,392	.47	23,893	

These tests show a decided gain on the fluxed iron, although it would be much more brittle than that made with the hematite mixture, which was a strong iron selected for a particular use.

The chemical analyses of the first six mechanical test results are given below, but it appears to the writer that the silicon content is too low, as the iron was fairly soft, i. e., a good metal for turning and boring, and silica linings were used in both cupola and ladles, and although the sodium in the flux would probably to some extent reduce the silicon in the fluxed bars, it could not possibly reduce silicon where it was not present. The analyses are as follow:

	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Graphite . . . . .	3.417	3.125	3.308	2.152	2.205	2.318
Combined carbon . . .	0.299	0.609	0.647	1.028	0.900	0.866
Silicon . . . . .	0.205	0.160	0.199	0.129	0.172	0.171
Sulphur . . . . .	0.049	0.008	0.025	0.154	0.159	0.160
Phosphorus . . . . .	0.052	0.052	0.043	0.706	0.805	0.819
Manganese . . . . .	0.551	0.580	0.652	0.335	0.277	0.295
Iron by difference . . .	95.427	95.466	95.126	95.496	95.482	95.371

On closely examining the above figures, one is somewhat at a loss to see the cause of the gain in strength in the metal, and some other reason must be given for the increased strength of the metal other than that of the chemical alterations which are shown.

In another case where Luxemburg white iron (*blanche*) was experimented with, and which was tested for transverse stress only, the deflection was practically nothing, .06 per inch being the actual amount; but while the unfluxed bar had an ultimate strength of only 1,598.46 pounds per square inch, the fluxed bars gave 2,018.86 pounds, and 2,209.03 pounds, a gain of 420.40 pounds and 610.57 pounds respectively, which is a very considerable increase.

The only way the writer can account for the increase of strength is that the ferro-sodium fluxes remove the mechanical impurities in the metal, and so produces adhesion of the grains or particles of metal to a greater extent—but, anyhow, there is the fact that there is a gain in strength.



With aluminum the writer has not been able to gain the added strength so markedly as with ferro-sodium, but a closer and whiter metal seems to result than when there is no flux used. The contraction is, however, too great to use the ordinary patterns, as a rule, which, to say the least, is a serious drawback, especially on large castings, and in the writer's estimation ferro-sodium is the preferable flux.

In regard to cost, ferro-sodium in the new forms is decidedly the cheapest in the market, the cost only on the molten iron being not more than 10d. per ton or less, and the method of application is extremely simple, the powder being just thrown into the ladle when it is half full and stirred in with a rod, the action being practically over when the ladle is full, nothing then remaining to be done but to skim the metal during pouring.

Clearly any good flux is a desirable thing with the cheaper grades of iron, as it enables good, clean, sharp castings to be made, and although we may assume that every ironmaster produces the best foundry iron he can, there is no disguising the fact that the product from the furnaces is always more or less irregular in quality.

Pure iron would be useless, as a matter of fact, as in experiments where it has been produced, it has been found devoid of the necessary tenacity and strength to make it fit for practical use, therefore for the foundry it is useless to think of using pure iron.

What is wanted generally for foundry purposes is a mixture of irons giving a good average strength when the test bars are tested for both transverse and tensile stresses, and which is also of such a degree of hardness as to tool with comparative ease; and rarely can this be had unless some form of flux be used. It therefore follows that to get what we want in the way of clean iron castings some flux must be used, and for general practical use the writer prefers ferro-sodium to all others in the market, but it must be used as the makers direct.

In the same issue appears a paper by Oscar Simmersbach, dealing with the sulphur contents of coke and their relation to

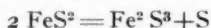
cupola practice. This paper was translated from "Stahl und Eisen" for the American Manufacturer, and is as follows:

**The Sulphur Contents of Coke in Their Relation to Blast Furnace and Cupola Practice.**

Among the chemical components of coke, sulphur occupies the first and most important place as regards injurious action, and it is for this reason that the blast furnace man has to give it his full consideration. The sulphur contents in coke depend upon three things, namely, on the sulphur contents in the coal, its chemical composition, and the quenching of the hot coke after drawing.

The sulphur in coal originates undoubtedly in most cases, and to the largest extent from iron pyrites which have entered into the coal after its deposition. The smallest part of the sulphur contents in coal occurs in the form of sulphates of which but very small quantities have been found so far. Most of the sulphur is present in organic combination, and, it is sometimes found in the form of iron pyrites in larger quantities. It is true, that doubts have recently been expressed by Dr. Haussermann, of Stuttgart, as to the presence of sulphur in organic combination, but, for the furnace man, the presence of organic sulphur in coal will remain a fact.

The iron pyrites in the coal are decomposed in the coke oven whereby, according to the equation—



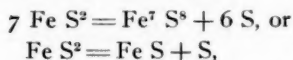
the fourth part of the sulphur contents would escape. Assuming a coke yield of 75 per cent from coal containing 1.5 per cent sulphur, the coke, according to the equation

$$\frac{1.5 \times 0.75}{0.75} = 1.5 \text{ per cent S,}$$

would contain just as much sulphur as the coal. If the coke yield be lower than 75 per cent the sulphur contents of the coke would become higher than that of the coal, for instance with a 70 per cent yield

$$\frac{1.5 \times 0.75}{0.70} = 1.6 \text{ per cent S.}$$

If less than the fourth part of the total sulphur should escape during coking, that is, should the desulphurization of the iron pyrites take place according to the equations



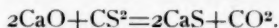
then there would be a lowering of the sulphur contents in the coke, and in the latter case the sulphur in the coke would amount to

$$\frac{1.5 \times 0.5}{0.75} = 1.00 \text{ per cent.}$$

The higher the coke yield, the more sulphur is released by the decomposition of the iron pyrites, other conditions being equal.

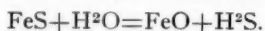
The sulphates established in coal ash are mostly reduced during the coking process, chiefly  $\text{Ca SO}_4$  to  $\text{CaS}$ . Of the organically combined sulphur more or less is also released, which, like that released by the decomposition of the iron pyrites could escape altogether, if the relations to the chemical composition of the coal ash were not to be considered.

Coal ash contains oxide, carbonate, and silicate of iron, and also combinations of lime and magnesia. The iron combinations are reduced in the coke oven, and at a comparatively low temperature, to metallic iron, which then, owing to its strong relation to sulphur, acts upon the released sulphur, and with it forms  $\text{FeS}$ . The more iron combinations in coal the more free sulphur is, of course, bound by combination. Lime and magnesia act in a similar manner. With the sulphurous carbon combinations originating from the free sulphur, both from sulphides, thus lime produces with sulpho-carbon sulphide of calcium, according to the equation



Even if considerable quantities of sulphur have become free in the coke oven, and therefore the possibility for the production of

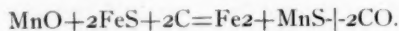
a coke poor in sulphur be given the sulphur contents in the coke will still be large when the coal ash shows large quantities of ferric calcium and magnesia combinations. This also explains why a low sulphur coke is not always obtained from a low sulphur coal, and that it even may happen that the coke shows more sulphur than the coal, although in quenching the hot coke with water a further desulphurization is effected by the removal of a part of the sulphides as sulphureted hydrogen, according to



This further desulphurization, however, is of less importance, as the structure of the coke, and especially that of dense coke, as well as the quick cooling of it do not favor a marked reduction of the sulphur contents by steam.

Tests by C. von John, of the Imperial German Geological Office, have shown that the coals belonging to the older carbon formation lose less sulphur in the coke oven than coals of more recent formation, lignites losing most.

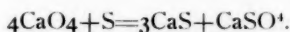
Sulphur in coke is injurious in the blast furnace because it goes down almost intact to the hearth where it is burned and gaseified together with the coke. The sulphur in the ore, on the other hand, is already subjected in the higher zones to various influences, and therefore comes into less contact with the molten iron. From the sulphur in coke there is developed before the tuyeres sulphurous acid, which during its ascent through the charge is partly reduced. The released sulphur forms with iron sulphuret of iron. A part of this is decomposed at high temperature by the joint action of silicic acid and carbon, while other parts combine with manganese according to the equation



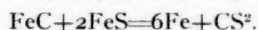
Still other parts are transformed together with lime and carbon into sulphide of calcium according to



By the basic earths, too, the ascending sulphurous acid is absorbed after completed reduction at high temperature, and from sulphate of lime sulphide of lime is formed according to



At a very high temperature there is a further decomposition of  $\text{FeS}_2$  by carbon, whereby sulphocarbon is produced:



From the sulphureted iron there also separates a part of the sulphur which escapes as sulphocarbon. The latter produces again with lime sulphide of lime, according to the equation



Sulphide of lime is insoluble in the iron bath, and is absorbed by the slag, just as sulphate of lime and the sulphides of magnesia and manganese, while the sulphuret of iron with its high specific gravity passes into the iron. The molecules of the sulphur metals push themselves between the slag molecules during the formation of the latter and combine with them. But as the sulphur metals play no part in the process of assimilation to which the continuously collecting masses of silicate are subjected, they act in an obstructive manner only, and delay the process. As a consequence, the slagging action of sulphurous slag is much smaller than that of slag of equal composition, but containing no sulphur metals. The principal means in blast furnace practice for rendering the sulphur in coke harmless is a sufficient addition of lime. It is true that even with acid slag a part of the sulphur is removed, because silicon acts upon sulphuret of iron in the presence of carbon, but lime exercises a more favorable and stronger action. As the separation of sulphide of lime takes place only under formation of acid slag, lime has to be present in excess so that the desired basic properties of the slag can be maintained.

Magnesia acts generally less desulphurizing than lime. This is evident from the fact that sulphide of magnesia possesses much less heat than sulphide of lime. Yet, on the other hand, practical results have shown that with the use of dolomite in the blast furnace more sulphur was absorbed by the slag than with limestone when the ore was poor in alumina.

High manganese contents in the slag originating from the melting of highly manganiferous ores or fluxes promote likewise

the absorption of the coke sulphur. At equal temperature, and charges being equally basic, the more sulphur is passed into the slag, the more manganese is present. Some authorities attribute even to manganese a stronger desulphurizing action than to lime.

It should never be ignored, however, that the temperature must always be sufficiently high, and that neither a large excess of lime or manganese will be able to remove the injurious admixtures after they have once entered the iron.

During the remelt of the pig iron in the cupola, the sulphur in coke is subjected to similar influences as in the blast furnace process. But the reaction of sulphur and manganese is less important here than that in the blast furnace, because there is generally but little manganese in the charge. By proper fluxing the total sulphur is passed into the slag, provided the temperature be high enough to convert sulphureted iron into sulphide of lime. Desulphurization is further promoted by basic lining. All this may well serve as an answer to the question, whether foundry coke may contain a maximum of  $1\frac{1}{4}$ , or  $1\frac{1}{2}$  per cent of sulphur as English foundrymen claim. At all events, foundry coke with 1 per cent sulphur will do more damage in the absence of sufficient flux, than coke with  $1\frac{1}{2}$  per cent sulphur and an ample addition of flux.

The injurious action of sulphur in the production of pig iron manifests itself, as is well known, by the fact that sulphur reduces the total carbon, and obstructs the formation of graphite, so that especially in the case of grey forge the injurious influence of the sulphur has to be removed. Sulphur also diminishes the fusibility and increases the hardness, but does not act to any considerable extent upon the properties of strength of the iron. In the cupola, iron with more than the usual sulphur contents easily becomes hard and white. It melts fast enough, but owing to its thick consistency it does not fill out the edges, points and sharp curves of the mold, and is, therefore, unfit for foundry purposes. The casting generally contains blow holes caused by escaping gases, such as sulpho-carbon gas. By bringing sulphurous iron into contact with wet sand the development of sulpho-hydrogen can be observed plainly.

High sulphur contents in coke constitute a pecuniary disadvantage in blast furnace practice, which in cupola work is felt less owing to the much smaller consumption of coke. Assuming that for the production of 1,000 kilos. of pig iron 1,600 kilos. of coke were required, as it is not unfrequently the case, there would be present if the coke contained 1 per cent sulphur 16 kilos. of sulphur which would be absorbed by  $16 \times 3.5$  or 56 kilos. of limestone. A furnace producing 80 tons of foundry iron daily would therefore require  $80 \times 56$  kilos. or 4.5 tons of limestone per day only on account of the sulphur in the coke. Besides, more flux requires more fuel, thus adding higher cost of fuel to higher cost of limestone. This loss will increase with the production of the furnace. From this it is easy to draw the conclusion that the less sulphur in coke the more profitable the working of the furnace.

Now, it is a matter of fact that nearly all coke shows an average of 1 per cent sulphur, and that with the present methods of coking desulphurization is impossible. It is possible, however, that by charging pressed coal lower sulphur contents in coke can be obtained owing to the absolute as well as relative increase of the carbon contents, as with the pressed charge less air enters the oven than with loose coal, whereby the loss of carbon by burning is diminished, and consequently the percentage of sulphur is decreased.

#### **THE FOUNDRY.**

The Avery molding machine, a new departure in molding, which is adaptable to a large range of ordinary castings, is illustrated in this issue.

R. D. Moore writes on the proper method of gating castings and the reasons why some castings are not solid.

Under "Cast Iron Notes" Mr. Keep answers some questions as follows:

"We have had complaint for some time of our castings being hard, causing great wear on tools used in facing them. The castings often contain porous spots while we want a close grained mixture. Can you suggest a cause for the trouble? We use No.



2 American Scotch, our own return and stove scrap in about equal proportions. The analysis of the casting is T. C. 3.14, Graphite 3.04, C. C. 0.10, Silicon 3.97, Phosphorus 0.612, Sulphur 0.054, Manganese 0.56."

For stove plate and light hardware castings it is an advantage to have silicon as high as 3.50. When it is much above that the surface of the castings often become very hard, though the center will be very soft. The surface of heavier parts of a casting having 3.97 per cent silicon will be harder than the surface of thinner parts.

The remedy in the above case is to use cheaper grades of iron. The iron which is called No. 2 is nearly a silvery iron, if it is not wholly so. By using 25 per cent of this iron, 25 per cent of good machinery scrap and the other half made up of return with sufficient stove scrap to complete the charge, the quality of the casting will be satisfactory.

No. 3 pig iron can be used in place of machinery scrap. The silicon should be reduced to about 2.75 per cent for this class of work, viz., pipe fittings, such as tees, ells, flanges, valves, etc.

This is a case which shows the difficulty experienced by the ordinary founder in using chemical analysis. He has paid out several dollars and has a complete analysis and does not know how to use it.

Everything about the mixture is exactly right, except the amount of silicon.

The first principle of foundry management is an understanding of the influence of silicon in cast iron. Ordinarily if a casting is hard an increase of silicon softens it, but after reaching 3.00 or 3.50 per cent, silicon hardens a casting. It is rare for the error to be on their side. It is well for every founder to have some quick, simple and inexpensive test which shall tell whether silicon is too high or too low, in other words, whether more or less silicon is needed.

If a test bar,  $\frac{1}{2}$ -inch square and 12 inches long, had been made from this iron it would have had a shrinkage of about .120 of an inch, while if silicon had been 2.75 the shrinkage would have been

about .150. Just as soon as the shrinkage tends up or down an increase or decrease of the soft pig iron will bring it back.

Using machinery scrap will close up the porous spots. Another reason for the use of a shop test is that the next lot of No. 2 pig iron will not have the same silicon as the last lot and the amount used must vary accordingly. A foundry mixture should never be allowed to vary enough to require a radical change, but slight changes should be made each day to keep the shrinkage uniform. Uniform shrinkage shows a uniform influence of silicon.

#### **Molding Test Bars.**

I have just received a test bar  $\frac{1}{2}$ -inch square and 12 inches long and am asked for an opinion. It broke at 503 pounds and has a very close, even grain.

The iron mixture is exceptionally good and seems well suited for machine castings as the shrinkage was .157.

The sand in which this bar was made was coarse and the molder was careless and allowed grains of loose sand to fall in the mold. As a consequence the edge of the bar which was at the bottom was very rough and full of notches.

Seeing this, I intended to place the rough side up in the testing machine, but from habit I placed it as usual in the same position as it lay in the mold.

In this case the fracture was through one of the small portions where the bar was perfect, and not through a notch as will usually happen.

If test bars are to be depended on for guidance they must be perfect. A chemical analysis would be of no value if the least inaccuracy was allowed.

In molding test bars the sand next the pattern should be as fine as brass sand or as No. 1 stove plate sand.

A smooth casting is stronger than one that is rough, because the uneven surface acts the same as a notch on one corner. The surface and corners, therefore, should be smooth and free from all imperfections. The test bar should be as near as is possible the same size as the pattern, and to make it unnecessary to mend

the mold the parting on the follow-board should be perfect. It is best to have two square test bars in one mold and to make two molds. This gives the average strength of four bars and the shrinkage can be measured on one of them. A careful molder will never have a defective test bar.

The test bar should be placed in the testing machine in the same position as it lay in the mold, because as the iron entered the mold the impurities which floated in the fluid iron and small bubbles of gas would rise to the top of the test bar, and would not influence the strength if tested in the same position. This is one of the reasons why the transverse test is best for cast iron.

Another reason is that the lower surface of a test bar will be slightly flat while the upper surface will be slightly concave, on account of the shrinkage of the metal. If tested top down the stress would come on the corners which would be lower than the center of the surface. As it is most convenient to mold a test bar with one corner down there will be two perfect sides, but the same side must always be placed down, therefore the lower side is always the side to which the gate is attached.

S. S. Knight contributes an article, relating some investigations conducted by him, as to the practical value of aluminum in connection with cast iron, in which he arrives at the conclusion that this metal does not possess the ability to strengthen weak iron, even when used in percentages that would make such mixtures far from economical.

J. P. Pero, under the caption "Economy in Melting," advances some arguments in favor of higher cupolas, from which we reproduced the following:

In noting the improvement in cupola construction during the past thirty years, we find the tendency has been to give prominence to the question of tuyere arrangement and size, with a view to the better distribution of blast. In fact, cupola improvement has consisted almost entirely in improved tuyere construction. There is a very important feature which has in a measure been improved, but the importance of which I believe is not fully appreciated. I refer to the height from bed to charging door.

Cupolas vary in height from 8 feet to 15 feet, and under the care of an observing man, all other conditions being equal, the ratios will vary almost in proportion.

By this statement I mean that the man who is not satisfied until he secures the best results with the least possible amount of fuel will find that the higher the charging door the less fuel will be required.

A little attention given to the working of the cupola at the charging door will quickly and thoroughly convince most men that the waste of heat in the shape of unconsumed gases is no inconsiderable amount.

I am aware that many cupolas are so constructed that the combustion is very satisfactory, yet even allowing that the combustion is perfect, there is still a vast amount of heat lost, which might be utilized with a different construction of cupola, viz: A greater height from bed to charging door.

Some years since I advocated the adoption of a plan of construction that would provide for a charging door 12 to 15 feet from the bed, and another about 10 feet above the first.

It would seem that in the modern foundry, equipped with elevators for getting up stock, that the greatest objection to this plan would be easily overcome; that is, the objection to the cost of getting stock to such a height. Perhaps you will think, if such a height is practical or desirable, why was it not adopted years ago? I believe the principal objection in the past has been that of getting up the stock and it has seemed almost impossible to get foundrymen to increase the height, even with the facilities now possessed for economically handling materials. I recall an instance: The manager of a modern foundry plant, contemplating the erection of a new cupola, came to me for advice in regard to the merits of several kinds of cupolas extensively known. We readily decided upon the particular kind to be used, but in sending figures for the construction of the cupola we disagreed on the height from bed to door. I urged him to adopt the plan here suggested, but while he admitted the plausibility of my argument, his conservatism, together with the fact that we knew of

no such plan in actual practice, induced him to decide upon the old plan of a single height of door. Even after reaching this conclusion an argument arose as to the height of the door. He had thoughtlessly planned his charging floor at such a height as to bring the height of the door but eight feet from the bed. I pleaded with him to rearrange his plans to make the height 15 feet, which he could easily have done, but he thought the appearance of the cupola house would be out of all proportion with the rest of the shop, so he finally decided upon 12 feet as the most convenient height. He has since told me that he regretted not adopting the double door plan, and admits that the 15 feet height would have been an improvement over the present plan. I think ultimately this cupola will be equipped with the double door. It would seem that to the practical man this plan would require no stronger argument than a study of blast furnace construction. Is there any result obtained in the working of a blast furnace that would not be desirable in a cupola furnace?

The great height of a blast furnace allows of a greater capacity for charges of fuel and ore; therefore less frequent charging. It also allows, or rather produces, a more gradual heating of the charges, thus preparing the charges for a more speedy fusion when the charge reaches the melting zone, a much desired result, as it is generally conceded that the less the iron is exposed to the direct force of the blast in its transition from the solid to the fluid state, the better the quality of the iron, and the greater height allows of a greater utilization of the heat produced in the melting zone, and which, forced by the blast, passes through the upper charges in escaping from the top of the cupola.

It perhaps may be asked: "Why not have the charging door 20 or 25 feet above the bed, and have but one charging door?" The idea of two doors is to use the lower one as a matter of convenience, in making the sand bed and in putting in the wood and first charges of fuel and iron.

In this connection I would suggest that instead of putting in the fuel alone before the fire is lighted, that the cupola be fully charged, or as nearly so as possible, before lighting the fire. The

very common practice of charging only the bed fuel and waiting until the fuel is well lighted is a decidedly extravagant practice. A great deal of heat is wasted that might under the other plan be utilized, and a great deal of fuel consumed unnecessarily. I have secured better results by charging the cupola in the regular way before lighting the fire.

My plan with the double door system would be to totally ignore the upper door until the cupola had been charged to the height of the lower door, then close and secure the lower door, calk the seams around the door on the inside with the clay used for daubing the cupola, and continue the charging from the upper door. This plan is suggested in connection with the plan of not lighting the fire until all charging is done. In case of poor draft, a gentle forcing by the blower will assure a good fire. The fire should be kindled a sufficient time before the regular blast is put on to allow the bed of fuel to become well ignited. Under these conditions there is less danger of needlessly burning out the bed than under the other plan of charging, as every atom of heat is absorbed in its passage to the top of the cupola. My experience has satisfied me of the superiority of the plan of charging as soon as the smoke of the wood has passed away, and of allowing the cupola to remain charged a reasonable time before putting on the blast. To illustrate: I know a foundry using a 45-inch cupola and melting from 20 to 25 tons daily; their practice is to light the fire at 11 a. m., begin charging at 1 p. m. and put on the blast at 2 p. m. In accordance with my plan the practice would be: Light the fire at 11 a. m., begin charging as soon as fire was well started, that is, wood consumed and bottom of coke well lighted, perhaps from 11:30 to 12 o'clock, and put on blast at 2; for I believe there is a great waste of fuel (because of the heat lost) in the two hours elapsing between the lighting of the fire and the beginning of the charging.

I am aware that in many foundries, particularly jobbing shops, the character of the work is such that the mixtures in the different charges vary greatly on different days, but I believe that the mixtures desired can be known sufficiently early to make

this plan thoroughly practical in every shop. The blast is a very important factor in the annual cost of melted iron. Too great a blast means an unnecessary destruction of the lining of the cupola, and a chance of impairing the quality of the iron by chilling, as well as the unnecessary wear of the blowing apparatus. It is the common practice to adopt a rule of a certain pressure in ounces for a given size of cupola; this rule should be used only as a guide or starting point to work from, as conditions vary so greatly that no rule can be adopted as infallible, and more dependence should be placed on judgment, based on experience, than on any inflexible rule.

#### **IRON MOLDERS' JOURNAL.**

William Osborne illustrates the molding of a paddle wheel center, when no pattern has been provided and the mold must be prepared with the aid of sweeps and core boxes.

Henry Hansen contributes an article, in which he asks the question, "Why Do We Use Facings?" He says:

It has been a standing joke for ages to tell an apprentice when he lost a casting that this dire result was brought about by the fact that he had put the parting sand on upside down. This is on a par with the practice of machinists in initiating candidates into the mysteries of their trade to send them after a left-handed monkey wrench.

But apprentices are not the only victims of an unsophisticated confidence in the doctrines of their elders. There are many molders past forty years of age imbued with habits equally as absurd as the impositions made upon the apprentice boy. Among these we may mention the universal reverence for facings, and a belief in the efficiency of these as a preventive against results caused by an imperfectly made mold.

There are many molders who will give facings credit for virtues they never possessed. Thus, sea-coal facing is claimed to vent a mold, but I have yet got to find the first man who will explain how this is accomplished. A mold scabs because the gases do not find a ready outlet. Gas must be confined before there can be a scab or cutting action on the surface of the mold



can take place. If a molding sand is too close-grained to permit the ready egress of the gases generated by the sand itself, how is it going to carry away the increased amount of gas produced by the addition of sea-coal? If anyone can explain, how we can add to a thing and have less, I shall be only too willing to take a course in his arithmetic.

If sea-coal were mixed with all the molding sand, its ability to carry away gases could be explained to be analogous to the carrying of water in a vein of gravel. As it is, sea-coal is only distributed in a small body of sand, placed in close proximity to the surface of the pattern, and how this sea-coal can possibly effect an outlet through a large body of heap sand with which it does not come in contact, is more than I can conceive.

Those who are inclined to believe that sea-coal does not greatly increase the amount of gas, which must be carried away, can determine for themselves that this is not so, by observing the pouring of two open sand plates, one made with sea-coal facing and one without. I know it is not customary to use facing on this kind of work, but I have seen it done and know that too many molders like to sneak a riddle of facing on such occasions, just because they have contracted the habit of facing everything they come to.

And I would ask those who claim that sea-coal facing will vent a mold and prevent cutting and scabbing, how it is that castings are lost from this defect every day? The greatest part of the castings, which are lost from these causes, have been molded with sea-coal facing, and if this material would do what they claim for it, there should be no loss. If a foundry could insure its molds against cutting and scabbing, by simply using sea-coal, there would be a great deal more used of this material than there is.

It is my sincere belief that more castings are lost and condemned from the use of too much facing rather than from not using enough. Whenever I pass a coldshut casting I cannot help but feel that some molder has wasted considerable energy in obtaining that result. He has turned out a shiner and it is

worthless. He may try to convince his foreman that the casting would have been all right if the iron had been hotter, but I will bet if he had spent less time mixing facing and putting on blacking, that he would have had a good casting. Many shops complaining of their castings being hard, coldshut and afflicted with blowholes, find their troubles entirely disappear upon a cessation in the use of facings instead of kicking at the cupola tender for not having the iron hot enough. I would stop the molders, who complained of dull iron, from using facing. It would hit two birds at one shot, saving fuel in melting and the cost of facing.

All facings are used simply to peel the casting. This is the only object we can account for in using them. If a mold is not prepared right, all the facing we can put in the sand or on the surface of the mold will not prevent our bad work from making itself known. Nobody would make a bad casting if facings would cure inferior work. There would be no use to have good mechanics if any scrub could make good castings if he was merely furnished a pile of facing.

#### **THE METAL WORKER.**

Thos. F. Kennedy, writing in this journal of the "Plaster Match," gives the following advice to those called upon to prepare such:

Prepare the drag the same as for any other match. Draw the pattern or patterns, and with a sponge or piece of waste give it or them a coat of some heavy oil; common lubricating oil will do. Be sure not to leave any spot, especially along the edge, uncovered, as plaster of paris adheres to bare iron, and when the pattern was drawn it would spoil the match. Plaster of paris, when mixed with its own bulk of water, forms a sticky paste which almost immediately becomes solid. Some qualities of plaster of paris absorb more water than others, and the quantity of water with which the best result may be obtained can only be found by experimenting with a handful of plaster. Different substances have been recommended from time to time as im-

proving the wearing qualities when mixed with the plaster, especially iron fillings. I have used the latter, however, but could not see that it made any perceptible difference. I do know, though, from actual experience, that the hardest and strongest matches are made with the least water. Of course, enough water must be used so that the mixture will be sufficiently plastic to take good impressions and fill all sharp edges and corners.

For very light matches the bottom board may be put on the frame and a hole made in it three or four inches square, according to the size of the match. Drive a few nails in it from the inside, allowing the heads to project so they will come close to the face of match when the frame is on, and have them long enough to go through the bottom board and clinch them on the outside. These will hold plaster better than if driven into the side of the frame, as is often done, even when the frame is deep enough to allow of a good groove being made around the inside. This is a wise precaution, and takes but a few minutes. In preparing to pour this kind of a plaster match, the mixture must be thin enough to run to the furthest corners and fill them. The joint between the drag and frame must be carefully stopped with clay or banked with sand to prevent the mixture running out. Build an inch of clay all around the pouring hole to give it a head, put some weights on the battens of the board, and it is ready to pour. Pour it quickly; don't dribble it. When full, and at intervals until it is settled, rap the frame gently with the hammer, which will agitate the plaster so as to assist any air to escape, and allow the plaster to settle homogeneously. It will shrink a little as it hardens, and it is well to have a little extra to pour in the head in case it gets too low. As soon as it is hard enough to move with safety, turn it over and lift off the drag; then clean off the sand so you can get at the pattern, and draw it out. Take the match to the water tank or hydrant, or pump, and wash off all sand; take the slick or trowel, and if the parting is high at any point it can be scraped off until right. Put the match now in the sun, or where there is a good current of air, and in an hour or so it will be ready for a coat of shellac varnish.

When this is dry it is ready for use. A good quality of this varnish is a great protection to a plaster match, and as soon as it shows signs of wear should be renewed.

Another way to make these matches is not to put any bottom board on the frame at all, but nail the battens direct to the frame, or put the bottom board on when the plaster is about settled. Less water is required by this method, hence stronger and harder matches can be obtained. Matches with less than an inch of plaster are difficult to make this way. Mix the plaster with just enough water to make it sufficiently plastic to give good impressions, and to run into sharp corners. Have a slight surplus of plaster mixed and tuck into the frame with the hands, leaving it the least shade higher than the frame. This done, get a piece of sheet steel or a sharp iron strike, and when the plaster is settled so it won't shrink any more, but is yet soft, pass the strike along the frame so as to bring the plaster flush with the frame, and then nail on the bottom board. It is always better to use a bottom board, as it gives support to the match, which the battens nailed to the frame do not. When the board is nailed roll the match over, lift off the drag and scrape away most of the adhering sand, so you can get at the face of the match, and then drive nails through the frame and face of the match, the same as in an oil match. Small nails or brads may also be pushed into the plaster along sharp edges and places that are liable to prove weak. All the nailing must be done quickly before the plaster gets too hard. The patterns should be rapped loose the first thing after the match is rolled over, but not drawn till the nailing is done. Small nails or brads may be stuck in the plaster close to the pattern when the match is made by the other method, also if it appears to need them. When the nailing is done draw the pattern, wash, examine the parting, dry and varnish, the same as when made by the other method.

The objection to plaster matches is that the working in and out of the pattern soon wears off the most essential part of the match, the sharp edges, and this in spite of the nails. Plaster is lighter than sand, its specific gravity being about the same as

wood. For this reason it has an advantage on large matches, which, if made of oil and sand, would be inconveniently heavy. As to which is cheaper, and easier to make, there is little choice, though the plaster is a little cheaper. I believe the oil match can be made quicker than one of plaster, and the plaster makes a great mess, no matter how careful one is. If it was nothing but cleaning the pattern after a plaster match, it is a disagreeable job. Matches when out of use are much better preserved by having the pattern on, and where patterns are not kept in a fire-proof vault, or otherwise especially provided for, this should be done. In case matches are stored without patterns they should never be piled one on top of another, but should be set on edge and allowed to lean lightly against each other. They will occupy just as little space this way as the other way. I know of a few oil matches that have been in use ten years, so that in point of durability there is no comparison between them and the plaster. If any reader of this article has had any experience that seems to conflict with any statement made herein I would be pleased to hear from him.